Pell Frischmann

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AFGHANISTAN RESOURCE CORRIDOR DEVELOPMENT:

WATER STRATEGY

FINAL KABUL RIVER BASIN REPORT

VERSION 4.0

Australian AID

The World Bank

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The World Bank has recently set up a team to help the Government of the Islamic Republic of Afghanistan prepare a “Resource Growth Corridor” strategy anchored to oncoming large mining investments. Aynak and Hajigak, with Kabul as a central node. The first major mine moving towards production is the Aynak copper mine, together with the oil blocks in Amu Darya, to be followed by Hajigak iron ore development and potentially the gas blocks in Sheberghan.

This report relates to a review of previous documents concerning water supply for Kabul and the copper mine at Aynak and their impact on a formal strategy for the Kabul river basin.

The Kabul river basin can be divided into three main sub-basins; Logar-Upper Kabul, Panjshir and Lower Kabul. The key sub-basin Logar-Upper Kabul provides only 2.5% of the average annual flow of the basin at the border with Pakistan, Panjshir provides roughly 14%, with the Lower Kabul and its significant tributaries providing the major part of the annual flow of this river. Transferring water from the Lower Kabul basin to supply Kabul is possible but implies significant technical and financial issues; this means that short and medium term solutions have to rely on the available water resources of the Logar-Upper Kabul basin or by transfer from the Panjshir basin.

The Master Plan for Kabul has projected significant population expansion at over 100% within 10-20 years with a corresponding increase in per capita water demand of up to 300%. This increase in water demand would be met by providing storage, extraction and transfer of water from the remote source of the Panjshir valley, both capital and annual operating costs of such a scheme are significant.

Water Supply and Demand

A possible balance of demand and supply for the 20 year period is provided in the following tables A, B and C:

Table A: Kabul City - Population Estimates

The following range of population estimates has been determined from the ranges quoted within available data from the references in given in Section 2.1:

Kabul City Population	2012	2022	2032
Low-range	3,200,000	3,900,000	4,800,000
Mid-range	4,000,000	5,000,000	6,000,000
Upper-range	5,000,000	6,100,000	7,000,000

Table B: Kabul City – Summary of Water Demand Estimates

The following range of total water demand including private wells has been estimated using the ranges of per capita demand based on the available data from the references given in Section 2.1. Figures are gross including network losses and unaccounted water:

Kabul City Water Demand	2012 (m3/day)	2022 (m3/day)	2032 m3/day)
Low range	98,800	198,000	485,800
Likely	125,000		
Upper range	154,000	323,300	792,500
Aynak Mine Water demand			
Estimated		35,000	35,000
Total (mid range)	**125,000**	**296,000**	**674,000**

Table C: Potential Water Supply

The following summary of potential water supply is taken from the sources listed in section 3.4, Table 3.5:

Total Water Supply	2012 (m3/day)	2022 (m3/day)	2032 (m3/day)
Available following investment	112,380	461,000	621,000
Total Potential yield	**121,700**	**714,500**	**1,287,500**

The city of Kabul currently relies on ground water from 4 aquifers in the Logar-Upper Kabul river basin. It is expected that the proposed copper mine and its ore processing facilities will also rely on an aquifer from the same river basin. If realistic demand projections are accepted and fresh water make-up for Aynak copper mine is minimised

then sufficient water could be supplied for Kabul City and Aynak Copper Mine for a medium term 10 year period utilising the following resources:

- existing ground water sources immediately surrounding Kabul;
- plus the provision of an impounding reservoir for surface water storage (Shatoot);
- and further use of the Logar river aquifers

It is only when significant investment has been delivered for water and sewerage infrastructure within the Kabul urban area, thus encouraging an increase in demand, that expensive transfer schemes from the Panjshir valley would be required.

With regard to Aynak copper mine the fresh water make-up should be minimised to the lowest level possible based on the latest technology for recycling process water. The initial water source would come from the Middle Logar aquifer and would be shared with Kabul City whilst the mine was being constructed and developed. Such an approach is dependent on further studies to determine the reliable yield from this aquifer and the impact of pumping on local users including irrigation in the vicinity of the potential well field. Investments associated with the mine should be used to provide additional storage on the Logar river or its tributaries. This storage would be used to compensate for mine extraction and river/aquifer recharge during dry weather or to counter supply and demand imbalances.

One major issue that must be resolved urgently is the increased level of pollution to the central aquifer supplying water to the majority of the inhabitants of Kabul. With virtually no wastewater collection and treatment infrastructure any increase in demand and extension of the piped potable water network will simply lead to even faster pollution of existing ground water sources. Extending the potable water network without equivalent expenditure for sewerage and associated treatment facilities should not be accepted.

The current unfunded Medium Term Program (MTP) for potable water infrastructure for Kabul has an estimate of 186 MUSD which could be completed within a maximum of 5 years. This investment would totally rely in existing ground water capacity from Kabul local aquifers. The medium term investment program to be completed within a 10-15 year period would include significant investment for wastewater collection and treatment and require a total budget including estimates for the MTP of around 953 MUSD. This investment would rely on new storage facilities and additional extraction from the middle and upper Logar river aquifers.

A long term program (20 years ahead and more) to provide potable water and wastewater collection and treatment for the majority of Kabul population has a budget estimate of almost 1,700 MUSD including the MTP and the medium term investments. Demand projections indicate that significant transfers from Panjshir basin would be required.

The short term investments for key studies have been budgeted at around 7MUSD. These studies are vital to finalising existing plans and gathering sufficient data to take appropriate decisions both for Kabul and also for Aynak.

Investment Funding

Finally but importantly it will be necessary define the funding mechanisms for the various schemes and the likely capital and operating cost investments required.

It should be noted that funding provided through the World Bank and other international agencies may be delayed through consideration of issues relating to a new Trans-Border agreement for the Kabul – Indus river basin between the Afghanistan and Pakistan governments. References have been made in news articles (e.g. Pakistan Today 22.01.12) to a meeting of the Pakistan Afghanistan Joint Economic Commission where commitments were made to negotiate a new “Kabul River Treaty” but this remains a contentious issue. This agreement may define certain limits on projects to be undertaken within the Kabul River Basin, based on concerns to maintain the flow in the River Indus and the terms negotiated between the parties.

Government Regulations: Licensing and Monitoring

Abstraction Licensing

The situation on water licensing is unclear from the reports and studies that have been reviewed. Environmental permits and licensing are the responsibility of the Afghan National Environmental Protection Agency (NEPA), but no specific reference exists for water licensing which should now be within the responsibilities of the Ministry of Energy and Water (MoEW).

To avoid unplanned depletion of water resources and to manage competition for water resources the government should implement a regime of water licensing and abstraction monitoring for all public, industrial, commercial and irrigation supplies. This will require a

licensing agency under the MoEW which should implement an agreed methodology for setting the available yields from water resources and sharing licensed quotas.

Charging for water

Tariffs for water and sewerage charges are in place through AUWSSC, however few customers actually pay the charges. (reference: meeting with Director General AUWSSC, Kabul, 08.04.12.) The tariffs will need to be applied within the framework of the current legislation with a clear methodology to account for income from charges.

The greatest challenge will be the ability of water customers to pay charges. It may be expected that when the public water network is extended the use of private wells will continue in order to minimise any liability for charges. In setting the level of charges the government is likely to take recognition of the difficult economic circumstances of the majority of the population.

Pollution prevention and enforcement

Pollution of groundwater and the local rivers is a major concern for the Kabul City area. Simple steps are needed to control pollution from sewage and encourage protection of the groundwater, which provides the only means of water supply for up to 4 million people. The sources of pollution are widely dispersed and will only be controlled with the support of the majority of the population.

A regime of regulation and enforcement will be needed within the new government regulations, but this will not be effective until practical measures have been taken to enable people to dispose of sewage from earth latrines and other waste in a safe manner.

Public Health Monitoring

From the information available within the various studies it appears that little or no monitoring is carried out for water quality, either for public supplies or to monitor for environmental risks. This is most likely caused by a lack of suitable laboratories, equipment and trained personnel to analyse samples.

The 2008 DACAAR analysis of water quality within aquifers beneath Kabul City indicates severe quality problems. In order to protect public health as far as practicable, public and private supplies must be analysed in a systematic way to determine levels of risks from contaminants.

1 PROJECT BACKGROUND AND OBJECTIVES

The World Bank has commissioned Pell Frischmann to undertake the development of a Water Supply Strategy with specific emphasis on the water supplies required for extraction and processing of mineral and hydrocarbon resources.

The Afghan economy must find new sources of growth if the transition and long-term stability are to succeed. The resources sector offers a window of opportunity (and challenges) during the next few years when potential mining investments by major international enterprises need to move into the production phase without further delay.

The second task of the assignment is to draw on the reports conducted so far to provide a suggested strategy for the development of water resources and management for the Kabul River Basin. Findings of this work are recorded in the First Interim Report (this report).

1.1 General Overview for Kabul Basin

Water supply for Kabul currently comes from ground water via individual wells using hand pumps, shallow and medium depth tube wells (privately owned) and a number of municipal wells.

Existing ground water aquifers have been efficiently exploited for some considerable time and have generally been able to provide good quality water for drinking and enough water for irrigation to ensure adequate food resource for the majority of the population.

The 30 years of conflict in the area has resulted in the breakdown of traditional methods of augmenting supplies from ground water combined with a significant increase in the size of the population of Kabul and hence water demand. The increasing demand in Kabul City exceeds current supply as it is evident that the aquifer below Kabul city is being depleted.

Dams have been provided in strategic locations mainly for hydro power generation; however no storage facilities have so far been developed to ensure adequate water resource for Kabul especially when there are other competing users for this resource.

The Kabul Basin is divided into the 3 distinct sub-basins:

- The Logar-Upper Kabul sub-basin
- The Panjshir sub-basin
- The Lower Kabul basin

1.1.1 Logar-Upper Kabul Sub-Basin

This sub-basin comprises two catchments: (a) the Upper Kabul river, which, with three small rivers, the Maidan, Paghman and Qargha, originates upstream of Kabul and flows through the centre of the city; and (b) the Logar river which drains a dry and hilly watershed south of the city. The Logar watershed comprises approximately 75 percent of the drainage area of the Logar-Kabul sub basin above the gauging site at Tangi Gharu. There is a modest but significant irrigated agriculture along the Logar river valley and in the river valleys upstream of Kabul. There are also several small hydroelectric stations on minor tributaries. However the dominant feature of this sub-basin is Kabul, which is the largest city in Afghanistan, and the economic and administrative centre of the country.

1.1.2 Panjshir Sub-basin

To the north of the Logar-Upper Kabul sub-basin is the Panjshir sub-basin formed by the Panjshir river and its principal and much smaller tributaries, the Ghorband, Salang and Shatul rivers. The upper portion of this sub-basin consists of steep mountain valleys in the Hindu Kush mountain range, which reaches over 6,000 metres above sea level and remains snow covered throughout the year. The southern portion of the sub-basin, namely the right bank areas of the Ghorband and Panjshir rivers near their confluence, opens onto a broad and gentle sloping fertile Shomali Plain which has some of the most important irrigated land in the basin. Downstream of the confluence with the Ghorband river and below the gauging station at Shukhi, the Panjshir river flows through a steep, narrow gorge until it joins the Upper Kabul river. Although the drainage area of the Panjshir river at Shukhi is smaller at approximately 84 percent compared with the Upper Kabul river at Tangi Gharu, its average annual flow is over 6 times as large.

1.1.3 The Lower Kabul Sub basin

The Lower Kabul sub basin extends from the confluence of the Panjshir and Upper Kabul rivers to the Pakistan border. It comprises two large watersheds to the north or left bank of the main stem of the river. These are (a) the Laghman, which includes the Alishang and Alimghar rivers; and (b) the Konar, which includes the Pech river and originates in Pakistan. There are numerous small tributaries on the right bank, including the Surkhrud near Jalalabad which with a population of approximately 120,000 is the only large city in the Lower Kabul sub basin.

The main stem of the Kabul river runs eastward from the confluence with the Upper Kabul and Panjshir rivers through a narrow gorge until its confluence with the Laghman river, where the valleys begins to widen. As the main stem of the river continues eastward the valley widens into a broad plain that comprises the second largest and important agricultural area in the Kabul river basin. Three dams and reservoirs have been constructed in this gorge for hydropower. The lowest reservoir in this cascade at Darunta is just upstream of Jalalabad and also provides municipal and irrigation water supply. Stream flow in the lower basin comes predominately from the two large mountainous watersheds namely the Laghman and the Konar whose higher snow and glacier covered areas reach nearly 6,500 metres above sea level.

1.2 Key Problems to be addressed for Kabul basin

1.2.1 Water Resources

All public supplies for Kabul City are currently taken from the shallow to medium depth aquifers below the city area (aquifer locations are shown in Chapter 3, Figure 3.1). Water is pumped from boreholes into local service reservoirs for distribution through a piped network. It should be noted that the public water supply has limited coverage with the majority of the population in the urban area taking their supplies from private wells.

1.2.2 Findings from the JICA Study

The following is an extract from a report within the JICA Study, (reference: The Study on Groundwater Resources Potential in Kabul Basin; Final Report: Executive Summary March 2011)

"1.3.1. Current Situation of Groundwater Sector:

Although the Kabul Basin is situated in semi-arid to arid zone, it had been a groundwater-blessed basin because the Paghman, the Kabul, and the Logar rivers flow into the basin bringing enough water to recharge groundwater in the basin. People living in the basin used to enjoy clean and enough amount of groundwater anywhere with springs, karezes and dug wells. However, due to increasing population and chaotic groundwater development, the quality and quantity of groundwater in the basin deteriorated rapidly in the past two or three decades. Over pumping condition of the groundwater was highly-publicized recently, however, actual evidence of over-pumping was not ascertained.

[Next paragraph omitted]

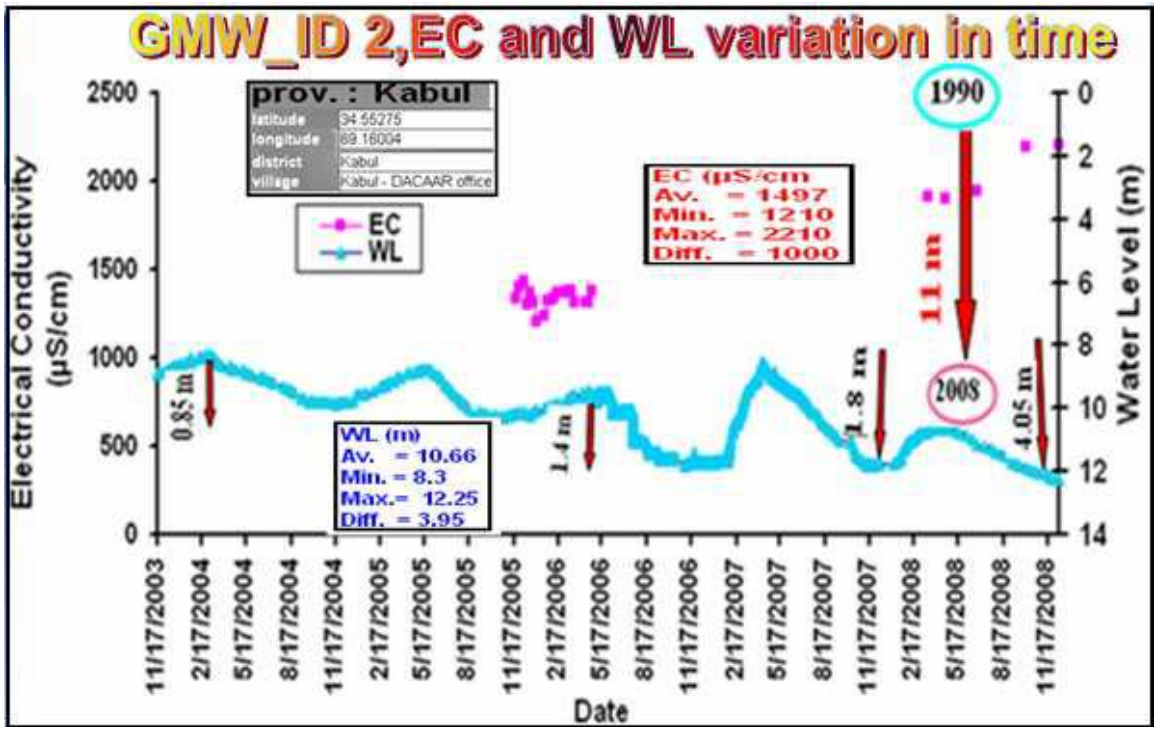
The groundwater sector in Kabul has been beset by many problems as stated below:

- Improper latrine facilities in houses, unregulated refuse disposal, and opened sewerage channels are causing contamination in the shallow groundwater.
- Waste water from both domestic and industrial uses is freely released to Kabul River, and pollutes river water and groundwater consequently.
- Only the groundwater is the resource for water supply of the city. However, majority of the citizen of Kabul City do not know the severe situation of groundwater resources and apt to abuse or stretch much water.
- The government agencies responsible in managing groundwater development do not have long-term perspective (master plan) and are rarely equipped with necessary information, equipment and technologies."

The JICA Master Plan (2009) for Kabul estimated the total water production taken for public supply as 40,000 m^3/d through the AUWSSC (Afghanistan Urban Water Supply and Sewerage Corporation) system plus a further 16,000 m^3/d taken through the separate Microroyan apartment development. Adding water taken from private wells within the city area, the JICA Master Plan estimated that the total water drawn from the local aquifers beneath Kabul was 120,000 m^3/d in 2008 for an assumed total population of 4 Million. This population is believed to be an over estimate; the Afghanistan Statistical Yearbook 2010-11 quotes the population for the urban area as 3,071,000.

The later JICA Report on groundwater resources in the Kabul basin in March 2011 gives increased total water production for public supplies including Microroyan at 69,000 m^3/d. Local aquifers are unable to sustain current demand and are being depleted with the result that new resources are required. This is demonstrated by the drop in ground water level in the aquifer beneath central Kabul where a report carried out by DACAAR noted that the ground water level had fallen by 11m between 1990 and 2008, Data provided in Figure 1.1 below.

Figure 1.1 Conductivity and Groundwater Level in Kabul 2008 (DACAAR)



Source: DACAAR (Danish Committee for Aid to Afghan Refugees) report "Groundwater Natural Storage and Water Quality Concerns in Kabul Basin, Afghanistan, May 2010":

1.3 Public Water Supply System

The current water supply network contains an estimated total length of 500 km of pipe with 37,000 properties connected and 340 public taps serving an estimated 1 million population (2008 data from JICA Master Plan study team). The Microroyan development has its own water supply system serving a further estimated 100,000 population. Therefore in total an estimated 1.1 million population has access to the public supplies, with the remaining majority of people taking water from private boreholes and shallow wells.

1.4 Sanitation

The city has no sewer network in the central district and the only sewers are in the Microroyan development but with no functioning sewage treatment. Much liquid waste is discharged to surface water drains and watercourses, with solids taken away for fertiliser from septic and cess tanks, or earth toilets. It is known that waste is polluting the local aquifers which will to some extent recharge the aquifers increasing the volume but lowering the quality. However the extent of pollution of surface and groundwater will certainly increase if the availability of domestic water supplies is improved. This will in

turn lead to greater public health risks from disease and polluted water in both public water supplies and private wells.

1.5 Drinking Water Quality

The DACAAR (Danish) report "Groundwater Natural Storage and Water Quality Concerns in Kabul Basin, Afghanistan, May 2010" gives information from samples collected as part of the DACAAR/WSP National groundwater monitoring programme. The samples detected pollutant levels exceeding WHO standards and also high levels of coliform bacteria. The samples were taken from wells across the Kabul Basin which has four main aquifers along the course of the rivers:

- Lower Kabul River
- Logar River
- Upper Kabul River
- Paghman River

The samples detected the following water quality concerns, which were more acute in the main urban areas due to contamination from sewage:

- Salinity
- Nitrate
- Boron
- Bacteria
- Hardness

2 WATER DEMAND

2.1 Kabul City water Demand Projections to 2032

2.1.1 Kabul City: Population Estimates

Summary

Population estimates for the Kabul urban area are problematic; there have been changes to city boundaries over the last decade, official statistics from the Afghan Central Statistics Office probably do not include many of the returned refugees that live within the urban area, and populations held by District Heads within the city are often different from the official statistics. The resulting % growth rates per year that have been estimated by various organisations can therefore be misinterpreted.

The following range of population estimates has been determined using the ranges quoted within available data from the references below:

Table 2.1 Kabul City - Population Estimates

Kabul City Population	2012	2022	2032
Low-range (#1)	3,200,000	3,900,000	4,800,000
Mid-range (#2)	4,000,000	5,000,000	6,000,000
Upper-range (#3)	5,000,000	6,100,000	7,000,000

1. CSO figures as base: references a) and b)
2. Mid range of other estimates: references a) and c)
3. JICA Study figures as base: references d) and e)

References

a) Reference: JICA EIDJR09108 Main Report 01, Page 1-9

The official statistics by the Central Statistics Office (CSO) put the population in the Kabul city at 2,967,600 in 2008. This estimate is largely considered an underestimation without accounting for the returned refugees and internally displaced. The general consensus exists among those involved in development works that the city population is in the range of 3.5-4.5 million more or less.

Recently, the Indian study team (led by ICT, a private consulting firm based in New Delhi) working on the structure planning for the city put the population at 4,532,703 based on the data reported by district heads.

The population data reported by the respective district heads or in the district passports, however, are not necessarily reliable. There exist obvious anomalies in the population of some district passports.

b) Reference Afghan Statistical Yearbook 2010-11 (Afghanistan CSO): Page 7 Table 2.2

[Extract from *Table 2.2 Settled Population by Province 2010-11, Figures in Thousands*]

Kabul Province	*Total*	*3691.4*
	Rural	*620.0*
	Urban	*3071.4*

c) Reference: USGS sir2009-5262;

Conceptual Model of Water Resources in the Kabul Basin, Afghanistan: Page 71

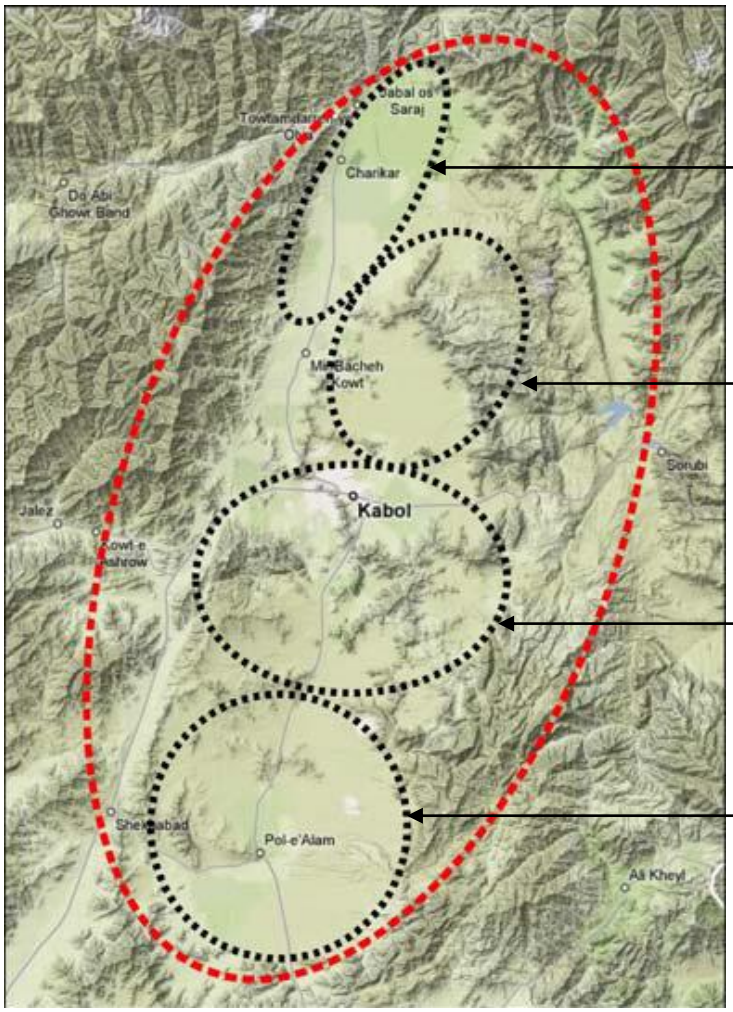
The total population in the Kabul Basin was estimated to be approximately 3.5 million in 2002, with about 80 percent of the population in the city of Kabul, and is anticipated to increase by approximately 20 percent by the year 2012.

Based on United Nations projections, the population in the Kabul Basin is estimated to increase from about 3.3 million in 2007 to about 9 million by the year 2057.

d) Reference: JICA EIDJR09107 Executive Summary Page 6

Figure 3.1 Population Projection in National Capital Region of Kabul

The population in different parts of the national capital region of Kabul (NCRK) is projected as shown in Figure 3.1. As shown, the new city will be developed to reach population of 1.5 million in 2025.



Northern region:
1.0 million ⇒ 2.0 million

New city:
0.1 million ⇒ 1.5 million

Kabul city:
4.0 million ⇒ 5.0 million

Southern region:
0.3 million ⇒ 0.5 million

NCRK Total:
5.2 million ⇒ 9.0 million

[Author's note: JICA Study projections for population 2008 ⇒ 2025. The 2008 total shown is incorrect; the figures sum to 5.4 million]

e) <u>Reference: JICA EIDJR09108 Sector 3 Water Resources 01: Page 3-9, Table 3.6</u>

[Extract from *Table 3.6 Projected Population and Water Demand in Kabul City and Other Cities in Upper Kabul River Basin and Panjshir Sub-basin*]

	2010/Short-term	*2015/Mid-term*	*2030/Long-term*
Kabul Population	*3,757,600*	*4,617,900*	*6,823,200*

2.1.2 Kabul City: Per Capita Water Demand

Summary

Normal practice would be that the per capita consumption is forecast using the existing consumption as a base level. However the accuracy of data available is limited by lack of records of actual water supplied per connection and lack of systematic methods for calculating losses within the network. Previous studies have therefore estimated the per capita demand by making assumptions for network losses.

Additionally the water network is estimated to supply only 13.5% of the population by property connections plus another 14% from public taps, in total up to 27.5% of population having access to the public supply from AUWSSC. [Source: JICA_EIDJR09108 Sector 5 Water Supply and Sewerage: Page 1-4, paragraph 1.3.1]

Direct comparison with other countries is difficult given the under developed nature of the city infrastructure, the arid climate and the ready availability of local groundwater. As an example developed countries in Western Europe would have a mid range per capita consumption of between 115 LCD (Germany) and 150 LCD (England and Wales). [Source: Environment-Agency.gove.uk: International comparisons of domestic per capita consumption 2008] The public water networks in these countries have nearly 100% coverage and properties are fitted with a wide range of modern water using appliances. Household sizes tend to be small in the range 2.1 to 2.4 people per property, in comparison to the large household sizes of up to 12 people quoted for Kabul.

These statistics indicate that Kabul citizens will in general tend to use less water per capita than those in a fully developed European city for the following reasons:

- Limited access to modern water using appliances
- General use of earth latrines rather than flush toilets in traditional properties
- Lack of sewerage system to take away liquid waste in large volumes
- Large household sizes hence more efficient use of water for food preparation etc

Figures quoted in the JICA study for neighbouring countries indicate a range from 80LCD (Syria and Jordan) up to 250LCD in Egypt (provincial capital including commercial and government consumption).

The planning figures for per capita demand quoted in the JICA study therefore appear reasonable at the lower range of 50-60LCD rising to 100-120 LCD in 2030 [see reference a) below].

The following range of per capita demand estimates has been determined using the ranges quoted within available data from the references in 3.2.2 below:

Table 2.2 Kabul City – Per Capita Water Demand Estimates

Per Capita Demand (excludes allowance for network losses)		2012 (LCD)	2022 (LCD)	2032 (LCD)
Lower-range (#1)	Supply connection	35	50	70
	Public tap			
	Private well	25	25	25
		15	20	25
Upper-range (#2)	Supply connection	60	100	120
	Public tap			
	Private well	30	30	30
		25	25	25

1. JICA Study calculations from AUWSSC data: reference b) and d)
2. JICA Study figures: reference a)

References

a) Reference: JICA EIDJR09108 Sector 3 Water Resources 01: Page 3-9, Table 3.5

[Extract from *Table 3.5 Unit Water Demand*]

	2010/Short-term (LCD)	*2015/Mid-term (LCD)*	*2030/Long-term (LCD)*
Kabul	*60*	*100*	*120*
Other Cities in the Basin	*50*	*80*	*100*
Rural area	*25*	*40*	*60*

b) Reference: JICA EIDJR09108 Sector 5 Water Supply and Sewerage: Page 1-5

Para 1.3.4 Per capita water supply and consumption

Based on the data and the estimates presented above [para. 1.3.3], the per capita water supply and consumption is calculated as follows. The unit water supply by CAWSS is estimated at 40LCD and calculated to be 91LCD on the accounted basis. The unit consumption of CAWSS piped water is calculated to be 26LCD on the estimate basis and 32LCD on the accounted basis. The unit water supply by the Microroyan system is calculated to be 160LCD and the unit consumption 125LCD.

For the combined water supply for the Kabul city as a whole, the unit water supply is calculated to be 51LCD on estimate basis and 104LCD on the accounted basis. The overall unit consumption is calculated to be 35LCD on the estimate basis and 49LCD on the accounted basis.

c) Reference: JICA EIDJR09108 Sector 5 Water Supply and Sewerage: Page 1-7

Table 1.9 Increase in Unit Water Consumption Assumed by Action Plan

[Author's note: This table refers to the CAWSS Action Plan from 2005 to 2015; units not stated but assumed LCD]

	Types of user as of 2003				
	User in traditional dwellings			*High standard user*	*User living flats*
Source	*Outside well User*	*Private well user*	*House connection customer*	*House connection customer*	*House connection customer*
Outside well	*15-15-15*	*0-0-0*	*0-0-0*	*0-0-0*	*0-0-0*
Private well	*0-0-0*	*33-25-17*	*20-15-10*	*125-87-50*	*0-0-0*
House connection	*0-0-0*	*17-25-33*	*30-35-40*	*25-63-100*	*100-112-125*
Total	*15-15-15*	*50-50-50*	*50-50-50*	*150-150-150*	*100-112-125*
Note: Figures show the evolution for the years of 2005, 2010 and 2015.					

d) Reference: JICA EIDJR09108 Sector 5 Water Supply and Sewerage: Page 3-1

3.1.1 Summary of water supply situations in Kabul city

The service population accounted for the piped water supply in the Kabul city is estimated at 540,000. Its coverage is estimated at 13.5% of the city population. However, the unaccounted service population is estimated at 560,000, including public tap users. Considering the unaccounted population, the service population of the piped water supply is estimated at 1.1 million, representing 27.5% of the city population.

The total of 56,000m^3/day of water is supplied through pipelines. Out of this, 38,500m^3/day is estimated to be delivered to residents. The balance of 17,500m^3/day is considered as physical loss.

The delivered water per capita is calculated at 35LCD on average. For house connections, the unit consumption is estimated at a level of 30-40LCD for users living in villas and traditional dwellings and at 100-125LCD for users living in flats. The unit consumption of public tap users may be at a level of 15-25LCD. The levels of water

consumption at 15-25LCD or 30-40LCD are considered quite low. Most residents extract groundwater from shallow wells located throughout the city although the volume is not measured.

The remaining 2.9 million people do not have the access to the piped water supply. No data are available for their unit consumption. MORRD indicates the unit water consumption at 25LCD for the residents having no house connections as a planning criterion. Assuming that 2.9 million persons extract the groundwater at 25LCD, the total water consumption is estimated to be 72,500m^3/day.

In total, the present groundwater extraction is estimated to be more than 120,000m^3/day, which exceeds the local groundwater potential. [Author's note: based on an assumed population of 4 million; MORRD is the Ministry of Rural Reconstruction and Development]

e) Reference: JICA EIDJR09108 Sector 5 Water Supply and Sewerage: Page 4-4

Table 4.3 Possible Water Allocation and Consumption for Existing Kabul City

Category		*Population*	*Supply*		*Consumption*			
			LCD	*m^3/d*	*LCD*	*m^3/d*	*LCD*	*m^3/d*
Non-piped service area (not covered by CAWSS)		*2,500,000*	*25*	*62,500*	*25*	*62,500*	*25*	*62,500*
Piped water supply (CAWSS service area)	*House connection*	*1,750,000*	*67*	*167,500*	*53.6*	*134,000*	*66*	*115,250*
	Public tap	*750,000*					*25*	*18,750*
Total		*5,000,000*		*230,000*		*196,500*		*196,500*
Note: 20% of loss is considered between amount supplied and amount consumed for piped water supply. *Source: JICA Study Team.*								

f) Reference: JICA_EIDJR09108 Sector 5 Water Supply and Sewerage: Page 5-3

Table 5.2 Water Allocation for KMA, 2025

Zone	*Category*	*Population*		*Water sup. (Mm^3/y)*	*Water sup. (LCD)*	*Water resources (Mm^3/y)*
Zone 1 Existing Kabul city	*House connection*	*1,810,970*	*39%*	*63.27*	*67*	*LGW: 13.9 Shatoot: 49.3*
	Public tap	*776,130*	*17%*			
	Shallow well	*2,438,270*	*53%*	*22.25*	*25*	*LGW: 22.3*
	Industrial water	*-------*		*9.10*		*Kabul river: 9.1*
Zone 2 New city	*House connection*	*1,499,721*	*100%*	*82.11*	*150*	*Panjshir fan: 37.6 Gulbahar: 37.7 26 Dalwa well: 6.8*
	Public tap	*0*				
	Shallow well	*0*				
	Industrial water	*-------*		*14.00*		*Panjshir fan: 7.0 Gulbahar: 7.0*
Zone 3 District 17 of Kabul	*House connection*	*0*				
	Public tap	*143,950*	*67%*	*2.63*	*50*	*Shah-wa-Arus: 2.6*
	Shallow well	*69,943*	*33%*	*1.02*	*40*	*LGW: 1.0*
LGW Local Groundwater						

2.1.3 Network Losses and Unaccounted Water

The analysis of population, water consumption and total water demand is only possible by using estimated data due to the lack of census records for population and accurate metered water consumption. Losses within the public water supply network have been estimated in the JICA Study at 35%, and unaccounted water at 30%, of the total volume supplied [Source: JICA_EIDJR09108 Sector 5 Water Supply and Sewerage: Page 1-5]. Losses may result from deterioration of the infrastructure due to lack of maintenance; "unaccounted" water is probably due to unauthorised connections to the network and public taps, or metering errors.

Network Losses

Based on the records held by AUWSSC, the JICA Study estimated losses in the older part of the network at 35% and at 25% for the more recent Microroyan system. In the absence of accurate data an average figure of 33% losses has been assumed in calculating the future demand in the area of the existing network. New infrastructure if installed correctly and with good quality material should have minimal leakage, however for refurbishment and extensions within Kabul a figure of 15% has been assumed.

Unaccounted Water

Unaccounted (non-revenue) water is of concern when forecasting and collecting income. However this water is not part of the network losses and is likely to be used as a supply to households through unauthorised and hence non-metered connections. In the absence of accurate metering data throughout the network the actual unaccounted water cannot be calculated. It has therefore been assumed as part of the gross supply to the population in calculating the future demand.

2.1.4 Kabul City: Water Demand Projections

Scenarios have been developed to represent potential growth over a 20 year period by modelling demand based on the increases in population and per capita demand as given Tables 2.1 and 2.2 above.

Scenarios are modelled on the mid-range population forecast currently estimated at 4,000,000 with sensitivity analysis for the low and upper population ranges.

Table 2.3A: Current (2012)

Supply Category		Population Served	Demand			Network losses (33%)	Total
			Range	LCD	m^3/d	m^3/d	m^3/d
Area not served by public supply network (private wells) [#1]		2,900,000	Lower	15	43,500	--	43,500
			Upper	25	72,500	--	72,500
Public Supply by AUWSSC [#2]	By service connection including Microroyan	600,000	Lower	35	21,000	10,500	31,500
			Upper	60	36,000	18,000	54,000
	Public Tap (340 No.)	500,000	Lower	25	12,500	6,300	18,800
			Upper	30	15,000	7,500	22,500
Industrial and Commercial allowance[#3]					5,000	--	5,000
TOTAL		**4,000,000**	**Lower**		**82,000**	**16,800**	**98,800**
			Upper		**128,500**	**25,500**	**154,000**
Sensitivity Low population/demand		3,200,000	Lower				86,800
High population/demand		5,000,000	Upper				179,000

Notes to Table 2.3A

1. Population served by private wells is the residual after deducting the population served by public supply from the total estimated population. The demand from private wells is estimated with no allowance for losses.
2. The connected population was estimated in 2008 as 440,000 with water supplied by AUWSSC connections plus 100,000 in the separate Microroyan supply area. Public

taps were estimated to supply a further 500,000 people. [source: JICA_EIDJR09108 Sector 5 Water Supply and Sewerage: Page 1-2, para. 1.3.1]

3. An allowance has been made for industrial and commercial consumption drawn direct from the aquifer using local wells. There is no data available to calculate the actual industrial or commercial demand.

Table 2.3B: 10 Year Horizon (2022)

Supply Category		Population Served	Demand			Network losses (av 25%) [#4]	Total
			Range	LCD	m^3/d	m^3/d	m^3/d
Area not served by public supply network (private wells) [#1]		2,400,000	Lower	20	48,000	--	48,000
			Upper	25	60,000	--	60,000
Public Supply by AUWSSC [#2]	By service connection	1,600,000	Lower	50	80,000	26,667	106,667
			Upper	100	160,000	53,333	213,333
	Public Tap (700 No.)	1,000,000	Lower	25	25,000	8,333	33,333
			Upper	30	30,000	10,000	40,000
Industrial and Commercial allowance[#3]					10,000	--	10,000
TOTAL		**5,000,000**	**Lower**		**163,000**	**35,000**	**198,000**
			Upper		**260,000**	**63,333**	**323,333**
Sensitivity Low population/demand		3,900,000	Lower				170,000
High population/demand		6,100,000	Upper				400,000

Notes to Table 2.3B

1. Population served by private wells is the residual after deducting the population served by public supply from the total estimated population. The demand from private wells is estimated with no allowance for losses.
2. It has been assumed that development of the network provides sufficient service connections to supply a further 1 million people and that the number of public taps is doubled to supply a further 500,000 people, thus increasing the population supplied by AUWSSC from 1.1 million in 2012 to 2.6 million in 2022.

3. An allowance has been made for industrial and commercial consumption drawn direct from the aquifer using local wells. There is no data available to calculate the actual industrial or commercial demand.
4. Network losses taken as 33% existing/ 15% new; average 25%

Table 2.3 C: 20 Year Horizon (2032)

Supply Category		Population Served	Demand			Network losses (25%)	Total
			Range	LCD	m^3/d	m^3/d	m^3/d
Area not served by public supply network (private wells) [#1]		500,000	Lower	25	12,500	--	12,500
			Upper	25	12,500	--	12,500
Public Supply by AUWSSC [#2]	By service connection	4,500,000	Lower	70	315,000	105,000	420,000
			Upper	120	540,000	180,000	720,000
	Public Tap (700 No.)	1,000,000	Lower	25	25,000	8,333	33,333
			Upper	30	30,000	10,000	40,000
Industrial and Commercial allowance[#3]					20,000	--	20,000
TOTAL		**6,000,000**	**Lower**		**372,500**	**113,333**	**485,833**
			Upper		**602,500**	**190,000**	**792,500**
Sensitivity [#4] Low population/demand		4,800,000	Lower				340,000
High population/demand		7,000,000	Upper				850,000

Notes to Table 2.3C

1. Population served by private wells is the residual after deducting the population served by public supply from the total estimated population. The demand from private wells is estimated with no allowance for losses.
2. It has been assumed that extensive development of the network provides sufficient service connections to supply 4.5 million people and that the number of public taps remains the same as 2022 to supply 1 million people in traditional dwellings.
3. An allowance has been made for industrial and commercial consumption drawn direct from the aquifer using local wells. There is no data available to calculate the actual industrial or commercial demand.

4. It has been assumed that the population difference is added to/ deducted from the population supplied through service connections with the population supplied by public taps and private wells remaining the same.

Summary

Table 2.4: Kabul City – Summary of Water Demand Estimates

Kabul City Water Demand	2012 (m3/d)	2022 (m3/d)	2032 (m3/d)
Low range	98,800	198,000	486,000
Likely	125,000		
Upper range	154,000	323,000	793,000

2.2 Mining

2.2.1 Aynak Copper Mine

The proposed copper mine located at Aynak some 40km South of Kabul requires significant quantities of water and power during its estimated 30 years life. Water is required for mining, the ore processing and refining operations, consumption at any camp site and for the makeup of any cooling water required for local power generation. There is a secondary requirement for water for remote power generation should this be provided from coal fired power stations; according to MCC the estimated load to produce Cathode grade copper is 280 MW.

The highest demand for fresh water comes from the ore concentration process and can be reduced by recovering and recycling process water before waste slurry (tailings) is deposited in tailings dams. The maximum water requirement indicated in the MCC scoping study is 69,000m^3/day for a net production of 200,000 tonnes of electrolytic copper. More recently MCC have indicated to the World Bank that a water demand of between 10,000 and 22,000 m^3/day would be required. Information available indicates that the dry solids content of tailings can reach 50% by the use of the most appropriate technology with some Chilean copper mines achieving even higher figures. Our estimate based on achieving the above tailings dry solids content and an estimate of water consumption for the mine and mine camp is 25,000 m^3/day which is at the very top of global best practice. Recent discussions with Chilean mining operators indicate fresh water requirements of between 16,000 to 24,000 m^3/day can be achieved, dependent on the ore concentration and dewatering process adopted for a production of 200,000 tonnes of electrolytic copper per year. A conservative estimate of 35,000m^3/day has been adopted in this report

2.2.2 Other Mines

There are current proposals for additional copper mines within the Aynak area; however it is doubtful that there is sufficient water resource within the immediate area to satisfy demand without significant investment in inter water-basin water transfer or very large storage schemes. An outline proposal is to include the interbasin transfer from Panjshir as part of the MOA (Memorandum of Agreement) for any new mine in the Aynak area.

Regarding the proposed iron ore mine at Hajigak the impact on the Kabul river basin is considered minimal as the main ore body lies within a sub-basin of the Amu Darya basin. Outline proposals are for the ore to be extracted using open pit working and then shipped by rail without further processing.

2.3 Irrigation

With the exception of the urban and peri-urban area of Kabul and the city of Jalalabad in the Lower Kabul sub-basin, the Kabul river basin is predominately rural and sparsely populated. Population growth rates are quite modest except Kabul. The population is concentrated along river courses and in the adjacent valleys where space and water are accessible for irrigating the summer crop. Consequently the construction of new storage reservoirs is likely to involve extensive resettlement and compensation of people displaced by the reservoirs.

Agriculture in the Kabul river basin is generally limited to land along the river valleys with access to the river for irrigation. The exceptions are the broad plan stretching southward from the Ghorband and Panjshir rivers, the lower Logar valley, areas adjacent to Kabul, and the wide valley of the Kabul river east of Jalalabad. These areas represent the greatest potential in the Kabul River basin for intensive cultivation of high-value crops. These large contiguous agricultural areas are also close to the primary transport routes and the largest economic centres.

Irrigation Channel in the Logar Valley – Photo via Google Earth

If water supply is reliable throughout the summer season, irrigated agriculture is intensive, intermittent irrigation is practices where access is more uncertain, both within the season and from year to year. There is also a relatively small area of rain-fed agriculture. The existing and potential irrigated areas within the Kabul River basin total approximately 352,000 hectares (ref Montreal Engineering company 1978 Vol 1 section 2.6).

Potential irrigated areas in the Upper Kabul and Panjshir basins are summarised in the following table:

Table 2.5 Irrigated Land Areas

Irrigated Area	River	Total area (hectares)
Logar-Upper Kabul		
Chak Wardak	Logar	3,750
Tangi Wardag	Logar	26,000
Lower Logar	Logar	10,500
Upper Kabul	Upper Kabul	28,740
East of Kabul	Recycled wastewater from Kabul	37,330
Panjshir		
Shomali Plain		53,130
Kapisa		20,170

[source Scoping Strategic Options for Development of the Kabul River Basin; World Bank]

At the low irrigation efficiency (30 percent) the water diversion requirement is about 13,636 m^3/hectare at an improved efficiency of approximately 45 percent the diversion requirement is approximately 9,131 m^3/hectare.

Ground water for Kabul is currently taken from the lower Logar and Upper Kabul aquifers at an estimated extraction rate of 90,000 m^3/day. Based on an irrigation requirement of 10,000 m^3/hectare the impact from extraction of the two aquifers is around 3,000 hectares or roughly 10% of the current irrigated area in the Lower Logar and Upper Kabul areas.

The impact of the estimated fresh water make up for Aynak copper mine at 35,000 m^3/day is equivalent to the irrigation of between 900 and 1,500 hectares, if the fresh

water requirement is taken over a year, however the impact is significantly reduced if the requirement is based on the normal 4month irrigation season where the impact drops to an average of 400 hectares.

In summary the proposed extraction from the Middle Logar aquifer via medium depth wells could be used to increase local irrigation as well as supply the fresh water makeup for the copper mine and the transfer of water to Kabul.

Without more reliable data on actual flows and the method of allocation of the available water resource the current and future requirements for irrigation is impossible to ascertain without further studies. However the extraction of 35,000 m^3/day for the mine does not seem to have a significant impact on the current irrigation demand during the 4 month summer growing season. The main impact on irrigation from the increased extraction from ground water aquifers for domestic consumption or for mines will be a reduced availability of local ground water aquifers feeding summer extended growing season. The full impact has yet to be determined however studies are clearly urgently required especially for the middle Logar river aquifer.

3 WATER SUPPLY SOURCES AND INFRASTRUCTURE

3.1 Logar-Upper Kabul Sub basin

3.1.1 Kabul Aquifers

The KfW study prepared an action plan based on the use of the available water resources, i.e. local groundwater. The action plan aimed at increasing local water production up to the potential yield. Accordingly, the planned service areas were still limited within the former boundary of the Kabul city.

The study estimated the local groundwater potential as shown in Table below, dividing the local aquifers into four. Locations of the aquifers are shown in Figure 3.1.

Figure 3.1 Aquifers Supplying Water for Kabul City

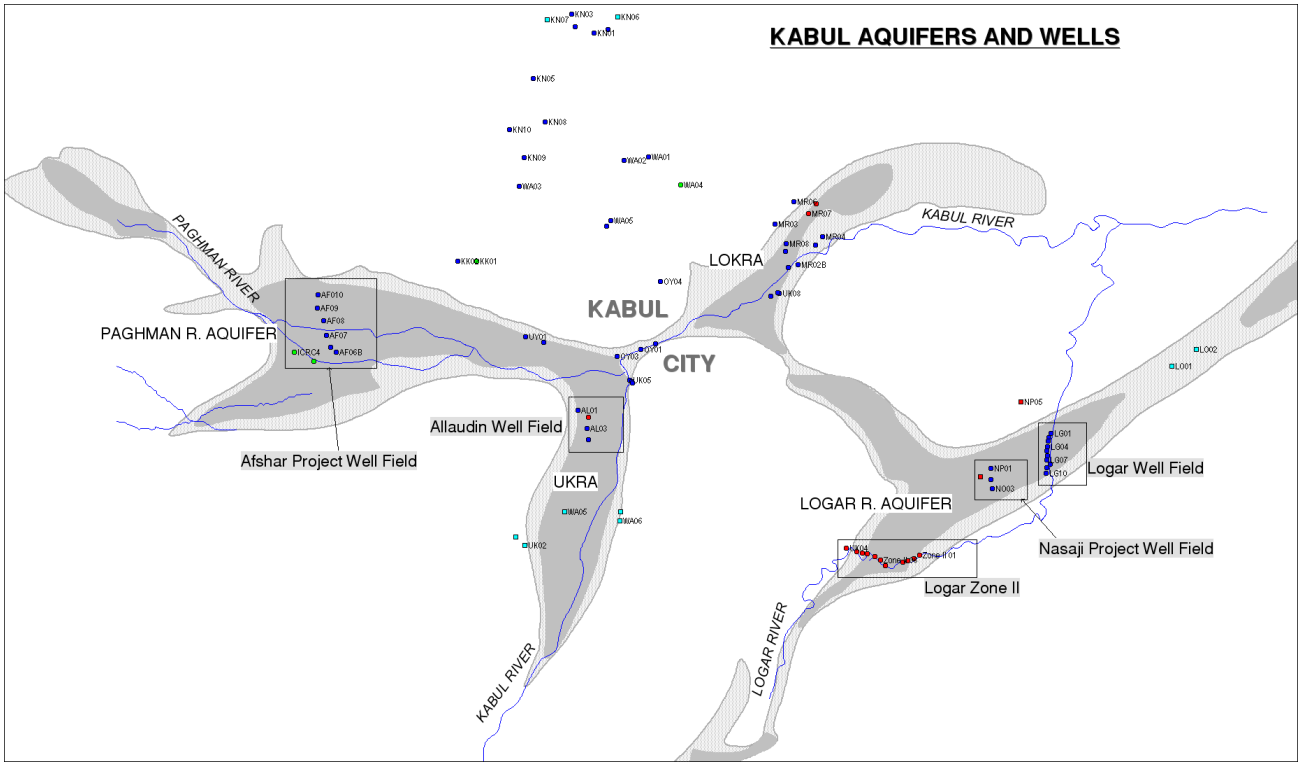


Table 3.1 Available Local Groundwater Potential within the Former Boundary of Kabul City

Aquifer	Current abstraction excl STP	Water Resource Availability	
	m^3/day	Mm^3/year	m^3/day
Lower Logar (Logar R Aquifer)	33,750	24.64	67,500
Allaudin and Upper Kabul	8,630	12.48	34,200
Asfer (Paghman River)	10,000	3.65	10,000
Lower Kabul (Lokra)	10.000	3.65	10,000
TOTAL	62,380	44.42	121,700

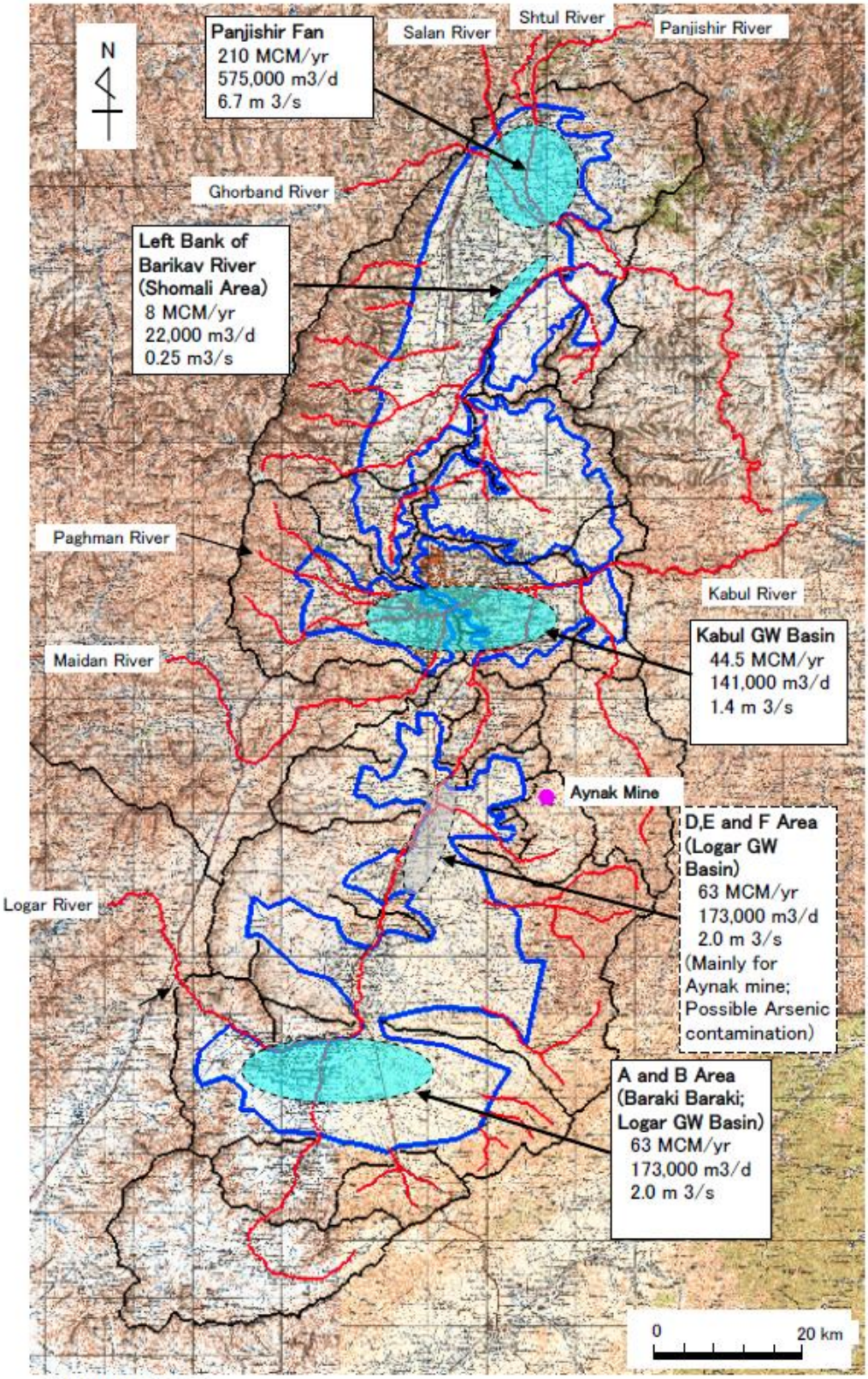
[Sources: Availability –JICA EID09108 Final Report Sector 05 Water Supply and Sewerage; Table 1.8, Page 1-6. Abstraction – AUWSSC data]

Note: excludes additional capacity made available under STP1 which is not yet finalised and extraction by private individuals from their own shallow wells.

It should be noted that the current lowest estimated demand at 98,800 m^3/day is significantly higher than this estimated current abstraction rate. Based on data provided in the DACAAR (Danish) report "Groundwater Natural Storage and Water Quality Concerns in Kabul Basin, Afghanistan, May 2010" indicates continued depletion of the aquifers within the City other than the Lower Logar Aquifer indicate that abstraction already exceeds availability in 3 out of the 4 aquifers.

Figure 3.2 Aquifers within the Kabul Region

The following diagram provides information on the known ground water aquifers within the Logar-Upper Kabul and Panjshir river basins:



< Explanation >

Potential area suitable for water supply

Potential area not suitable for water supply

GW Basin Boundary

Watershed Boundary

Main River

Note: The value shows GW potential for water supply for the Kabul metropolitan area.

3.1.2 Deep Aquifer

The JICA study on groundwater resource potential in Kabul Basin indicated that the so called “Deep Aquifer” contained “fossil Water” with very low recharge rates when wells drilled to a depth of 600m. The result of the study indicated that the aquifer could only be used as an emergency source of water for a part of Kabul demand. The study concluded that the deep wells installed under the study should be retained and monitored but not extended.

3.1.3 Logar Aquifers

There are three designated aquifers associated with the Logar river: Upper, Middle and Lower. Information on the Upper aquifer is limited but has significant potential yield for Kabul domestic water supply. The Middle aquifer has been extensively investigated by the Russians to provide fresh water for Aynak copper mine. A number of reports indicate potential arsenic contamination from copper ore mining/processing, however this is not substantiated in any qualitative analysis and must be checked prior to its use for potable water for any mine camp or for Kabul domestic supply or extended rural supplies. The potential yield from this aquifer could be used for the mine and also for Kabul and additional irrigation demand. The Lower aquifer is currently used to provide a significant part of Kabul ground water source and irrigation.

3.1.4 Shatoot Dam

A recently completed feasibility study by Pooyab Consulting Engineers of Tehran indicates that a dam at Shatoot on the Maidan river of the following characteristics is the most favourable under cost benefit analysis.

- Dam Height: 113.5 m
- Dam Body Type: Rock fill with Vertical Clay Core
- Total Reservoir Volume: 250 MCM
- Regulated Domestic Water Volume: 97.1 MCM/y
- Regulated Agricultural Water Volume: 20.8 MCM/y
- Regulated Environmental Water Volume: 13.1 MCM/y
- Total project Cost (for 250 MCM): $312.7 Million
    - Reservoir Damages (displacement, etc.): $11.4 Million
    - Dam: $193.3 Million
    - Conveyance pipeline: $14.79 Million

- Treatment Plant: $76.8 Million
- Irrigation: $16.4 Million

Water for Kabul would be treated at a conventional water treatment plant comprising settlement, rapid gravity filtration and disinfection before distribution into the Kabul city network. The construction of the dam is likely to have an impact on the potential yields from the Allaudin and Upper Kabul well field with an estimate in the JICA Main Report 01, case 1b indicating that construction of the dam will reduce the yield from 16.2 Mm^3/yr to 9.7Mm^3/yr.

3.1.5 Dams on the Logar River

A number of dams have been proposed along the length of the Logar river. Data taken from the Montreal Engineering report (Monenco 1978) indicated the following most promising sites:

Kajab: Potential storage of 290 Mm^3 with a dam height of 104m, cost estimate at that time was 108 MUSD. A more realistic current estimate would be in the order of 300 MUSD. Storage would be used for irrigation and to augment Logar river recharge during low flow.

Gat: Located close to Kabul with a potential storage of 105 Mm^3 at an estimate at the time of the report of 40.6 MUSD. This dam has now been rejected on the basis of significant relocation cost for people living in the area as identified in the JICA master plan and in comments from Afghan officials during recent meetings.

Kharwar Dam: Located on the Charkh river, this is a partially constructed masonry dam with work carried out in the period 1930-32. The conclusion of the Monenco report was that the dam was in the wrong location and required extensive design studies for a suitable dam section including the foundation treatment before any work should be undertaken. Not considered a priority for immediate investment.

Chak Wardak: Not reviewed under the report, constructed in 1938 as a small hydro-power diversion dam with a nominal storage capacity of 36 Mm^3. Current intention is for rehabilitation of the dam structures and associated units. Main use is irrigation for agriculture within the Logar valley.

Chak Wardak Dam - Photo via Google Earth

Sorkhab: Not reviewed under the report. Dam is located on a minor tributary of the Logar river joining the Logar downstream of Tangi Waghjan. Year of construction of the dam is unknown however is reported as 25m height of earth filled construction. Used for local storage and irrigation.

Sorkhab Dam - Photo via Google Earth

Other Locations: Other dam sites have been proposed at Tangi Waghjan, Tangi Wardag, however displacement cost and loss of land is significant and neither of the sites have been progressed to even pre-feasibility study stage.

Tangi Waghjan Dam possible site - Photo via Google Earth

Table 3.2: Existing dams in the Logar river basin

Name	Year of construction	Purpose	Type	Dam Ht	Nominal Capacity
Chak Wardak	1938	Hydro-power	Diversion	Unknown	3.6 Mm^3
Sorkhab	Unknown	Storage	Reservoir earth filled	25m	Unknown
Kharwar	1932-33	Storage	Reservoir earth filled	36m proposed but unfinished	Unknown

[source: KfW and JICA Studies]

Table 3.3: Proposals for Dams (source: KfW and JICA Studies)

Location	River	Dam height (m)	Gross storage (Mm^3)	Live storage (Mm^3)	Capital Cost (MUS$)	Cost/storage capacity (US$/$m^3$)
Haijan/Shatoot	Maidan	50	220	200	72	0.36
Kajab	Logar	85	400	365	207	0.57
Tangi Wardag	Logar	65	350	300	356	1.19
Shatoot (latest estimate Feb 2012 Pooyab)	Maidan	113.5	250	220	193.3	0.77

3.2 Panjshir Sub basin

The Panjshir sub basin has a potential water resource significantly in excess of the requirement for Kabul. However major investment has to be provided to transport water between 70-100km with a hydraulic lift of between 300-400m dependent on source location to reach Kabul. Two sources of water have been previously identified. The first surface water from the Panjshir river, either directly from the river at some convenient point below Gulbahar but above the confluence with the Ghorband river, or directly from a reservoir built on the Panjshir river upstream of Gulbahar. The second source is a shallow groundwater aquifer with a large area beneath the plain, south of the confluence of the Ghorband and Panjshir rivers. This aquifer has not previously been explored or investigated in detail, however it is understood that JICA are presently carrying out an in-depth study on the aquifer and the potential to transfer to Kabul, but preliminary hydrogeological surveys in the 1970's speculated on its extent and magnitude. Estimated yield of this aquifer is around 210 Mm^3/yr (575,000 m^3/d).

The JICA Study "For the development of the Master Plan for the Kabul Metropolitan area" concluded that the majority of domestic and industrial water should be transferred from the Panjshir sub-basin with dependence on ground water from local aquifers reduced to enable sufficient resource for shallow well users.

There are a number of medium term options, subject to funding, that could augment water supplies to Kabul, provide additional water for irrigation and also hydro power. The

current master plan for Kabul proposes using water from the Panjshir sub basin from a mixture of ground and surface water. Ground water would come from Panjshir fan aquifer once the extent and capability of the aquifer had been verified; Surface water would either come from a Panjshir river direct water intake or from impounding reservoirs on the Salang and or Panjshir rivers.

Table 3.4: Outline Information on Potential Dams

Location	River	Dam height (m)	Gross storage (Mm^3)	Live storage (Mm^3)	Installed capacity MW	Capital Cost (MUS$)	Cost/storage capacity (US$/$m^3$)
Salang	Salang	135	410	340	Na	332	0.976
Gulbahar	Panjshir	180	1,300	1,130	100	1,078	0.953

3.3 Aynak Copper Mine

Fresh water make-up for the mine should if possible come from two independent sources; one for regular use and another as an emergency supply if adverse weather or a security of supply situation prevails.

Ground water from the Middle Logar aquifer is the only local water source available in the short term for the mine. Its extraction should be monitored and controlled to cause the minimum disruption to other water users as required under the MOA signed between the mining company and Ministry of Mines. However providing an alternative secure supply is proving very difficult and will require significant additional work by MCC to develop the optimum and most economic solution.

The outline proposal in this report is for the following:

- Immediate test pumping of the middle Logar river aquifer to check on the aquifer reliable yield and the impact on local irrigation and rural users and any interconnection between the middle and lower aquifers which could have a significant impact on Kabul water supplies (refer to Chapter 5 - Strategy);
- Agreement on the fresh water requirements for the mine and outline proposals for its extraction to minimise local impact;

- The feasibility and cost of providing storage on the Logar river to ensure replenishment of the proposed water extraction for the mine; such an approach could provide the alternative standby supply for the mine;
- Detailed review of the design of tailing dams to ensure that the risk of pollution to the Logar river aquifers is minimised.

In addition studies should be undertaken to review the potential for enhanced aquifer recharge to reinforce the natural recharge which normally takes place during times of higher river flows. Some of the methods for enhancing aquifer recharge are described in Appendix 3; dependent on topography these methods can be engineered in a simple and cost effective way. Such an option has been clearly identified in the JICA study but appears to have never progressed towards feasibility study phase. Without a more careful study of the geology of the Logar river upstream of the mine the effectiveness of any recharge scheme on any of the Logar aquifers.

Outline summary use of the Middle Logar Aquifer Groundwater Source

MCC must consider environmental impact studies to assess alternative approaches for the mine construction, including phased commissioning and the associated impact on water extraction.

It is recommended that:

- Extraction from each well should be controlled to minimise the impact on other users;
- Impact on the Lower Logar aquifer used for Kabul public supplies should be investigated and monitored
- Wells should be located if possible away from the river and outside the main irrigated land area;
- Water extraction should be formally licensed and monitored, with requirements to reduce extraction when water levels in the aquifer fall below defined trigger points based on studies of the available yield;
- The wells should be designed based on survey data as described in the Screening Report for Aynak Copper Mine ESIA prepared for the MCC-JCC Aynak Minerals Company Ltd (MJAM) in March 2010 by Hagler Bailly Pakistan/SRK Consulting:
  - A preliminary hydrocensus over the project area, particularly the water supply areas, to identify the groundwater collection points;

- Measurement of water levels from selected representative water sources on a regular basis, along with the collection of information on water yield;
- Collection of water quality samples from these sites.

3.4 Summary Supply Situation

Kabul is currently supplied with ground water from four aquifers in and around the city. The aquifer under the city is being depleted and also heavily polluted by human and animal waste which will potentially make the aquifer unsuitable for human consumption without significant additional treatment and expansion of the cities piped water network.

Additional ground water sources could be made available from Logar river aquifers if studies indicate that ground water yields and quality are acceptable and agreement can be reached on such issues as security, compensation and or improvement in local rural services.

Additional storage facilities are urgently required, however development of dams tends to be protracted with the need to provide relocation and compensation to displaced farmers. Recent comments indicate that between 10-20 years can be required if land acquisition problems are not adequately addressed, however if resolved then construction can commence within a reasonable period of time once feasibility and related environmental studies have been approved..

Current plans propose new storage on the Maidan river relatively close to Kabul combined with transfer from the Panjshir basin. Both will require significant levels of capital investment and also investment in municipal water and wastewater infrastructure for the ever expanding Kabul.

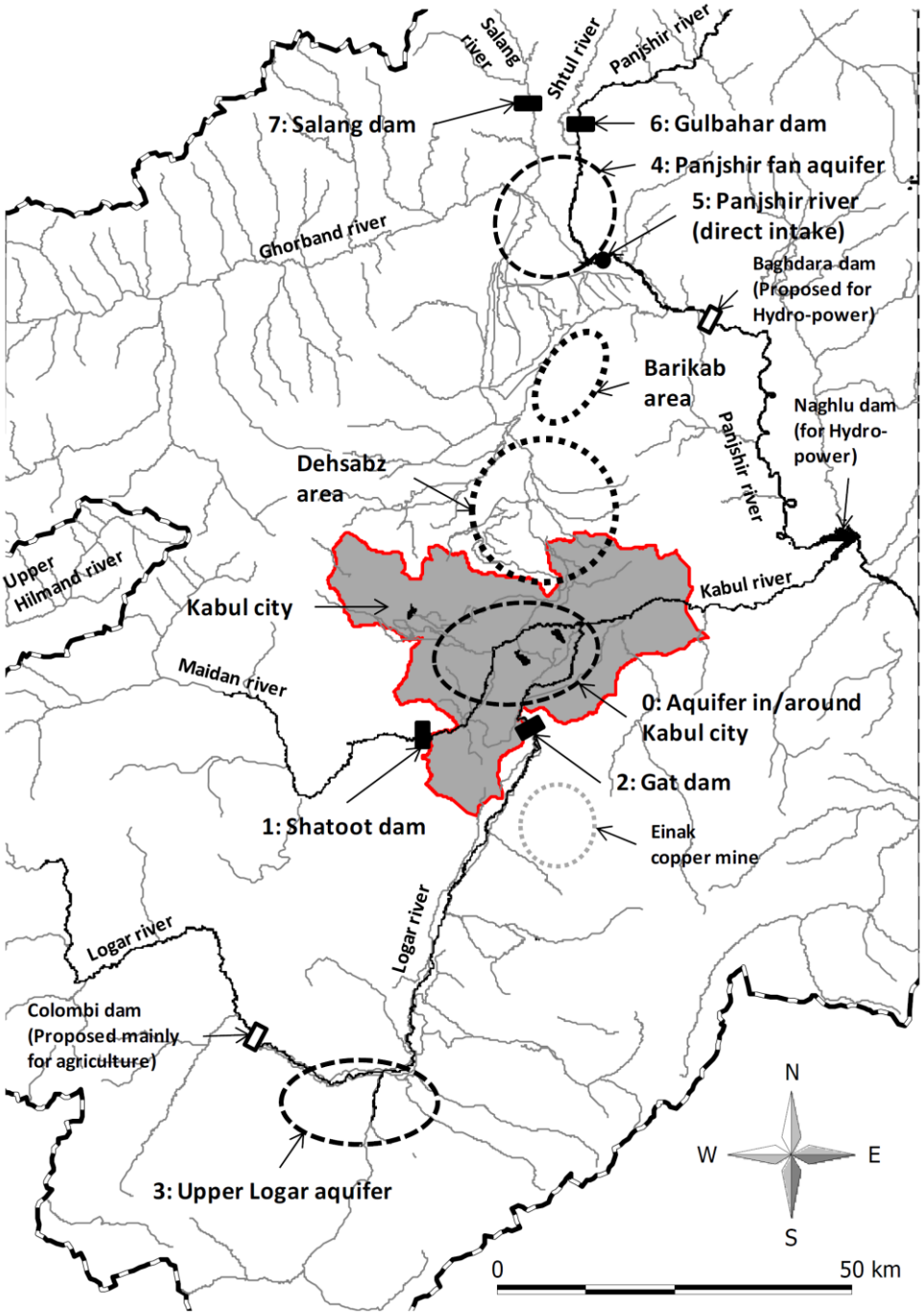
The summary situation is provided in the following table:

Table 3.5: Summary Water Supply Potential

Type	Location	Current/Proposed Abstraction m^3/day	Potential Yield m^3/day	Remarks
Current				
Ground water	Lower Logar river aquifer	33,750	67,500	Current abstraction excluding STP
Ground water	Allaudin and Upper Kabul	8,630	34,200	Current abstraction
Ground water	Asfer (Paghman river)	10,000	10,000	Current abstraction
Ground water	Lower Kabul (Lokra)	10,000	10,000	Current abstraction
Ground water	Shallow private wells	50,000		Estimated extraction from local private wells
	Total	**112,380**	**121,700**	Current proposal under Extension of Kabul Water Supply II program
Medium Term 10-15 Years				
Ground water	Lower Logar river aquifer	60,000	67,500	Extraction increased to max
Ground water	Allaudin and Upper Kabul	15,000	15,000	Extraction reduced due to Shatoot dam
Ground water	Asfer (Paghman river)	10,000	10,000	Max extraction
Ground water	Lower Kabul (Lokra)	10,000	10,000	Max extraction
Surface Water	Shatoot Dam	266,000	266,000	Design treated water flow
Ground water	Middle Logar Aquifer	50,000	173,000	35,000 m^3/day required for Aynak
Ground water	Upper Logar Aquifer	50,000	173,000	Medium extraction rate could be increased
	Total	**461,000**	**714,500**	
Long Term 30 Years				
Ground water	Lower Logar river aquifer	60,000	67,500	
Ground water	Allaudin and Upper Kabul	15,000	15,000	
Ground water	Asfer (Paghman river)	10,000	10,000	
Ground water	Lower Kabul (Lokra)	10,000	10,000	
Surface Water	Shatoot Dam	266,000	266,000	
Ground water	Middle Logar Aquifer	50,000	173,000	
Ground water	Upper Logar Aquifer	50,000	173,000	
Ground water	Panjshir fan aquifer	160,000	573,000	Single transfer main from Panjshir
	Total	**621,000**	**1,287,500**	

The following diagram from the JICA Final Report Sector Report 3 water resources provides an overview of the potential water sources in the Logar Upper Kabul and Panjshir basins. It should be noted that data on the Columbi dam is not available and the location of Kajab is just off the map at the upstream end of the Logar river.

The Study for the Development of the Master Plan for the Kabul Metropolitan Area in the Islamic Republic of Afghanistan
Final Report, Sector Report 3: Water Resources



Source: ibid.

4 GOVERNMENT REGULATIONS AND LICENSING

The following sections contain extracts from the JICA Study 2009 [reference: The Study for the Development of the Master Plan for the Kabul Metropolitan Area; Final Report, Sector Report 3: Water Resources, Chapter 3]. The new government ministries have adopted the titles given below which are now used in the government website. The Ministry of Energy and Water website is under development and shows some information on high level responsibilities and strategy but the full state of implementation for the new water law is unclear.

4.1 Water Law

A new Water Law was prepared as an output of Phase 2 of the Water Sector Reform Project. The draft was approved by the Cabinet and went through the process of approval by the President in 2009.

New Water Law Article 6 (Public usage of water resources) declares, “The water resources shall be used according to this law and in regard to the praiseworthy customs and the traditions of the Afghan people to meet the needs for drinking water, agriculture, livelihood, industry, public services, and generation of energy, transport, navigation, hatchery and environment. Priority for use of water resources shall be given to drinking water and livelihood.” This principle to give priority to drinking water and livelihood is maintained from the present Water Law.

Proposed major changes in the New Water Law are:

- Introduction of the concept of river basin management,
- Conversion of water rights in the present law to the permission, and
- Clear declaration of water resources conservation.

4.2 Organization and Responsibilities for the water sector

The new Water Law gives wider responsibilities to the Ministry of Energy and Water (MoEW) compared to present Law

- The development of water resources management national strategies in cooperation with line ministries and agencies

- The issue of licenses in accordance with the new Water Law
- MoEW also manages the main water uses. In the case of irrigation, main facilities such as canals to deliver water to irrigation fields are managed by MoEW and permission for water use is also managed by MoEW.

Related ministries and National Environmental Protection Agency (NEPA) set the standard for the quality of water in the sources for different users in accordance with international standards for potable water and water for livelihood use as per separate regulations. NEPA set the limits of contaminated water resources in cooperation with the Ministry of Public Health and other relevant institutions.

4.3 Water Management by Ministry of Energy and Water (MoEW)

The quoted strategy for water resources management is: “The Government will implement the integrated water resources management and river basin management approaches to planning and developing water resources in the short and medium-term. The national strategic goal is to manage and develop the water resources in the country, so as to reduce poverty, increase sustainable economic and social development, and improve the quality of life for all Afghans and ensure an adequate supply of water for future generations.”

4.4 Relative Importance of Irrigation

Based on information available in the JICA Master Plan Study for Kabul and others “Agriculture accounts for 95 % of water consumption. In the 1970s, some 3.6 million ha were cultivated using various irrigation methods, but at present only about 1.3 million ha of land are being irrigated. Of these, only 10 % is being irrigated using properly engineered systems with the remainder dependent on traditional irrigation methods, some of these based on run-offs or use of aquifers that are being degraded by deep water wells and insufficient investment in recharge basins.

Irrigated land has generally three times the productivity of rain-fed land. Out of 8.3 million ha of arable land in Afghanistan, 5.8 million ha is potentially irrigable. Irrigation water management is one of the highest priorities of the Government. Significant investment has gone into rehabilitating damaged or degraded irrigation systems, but little has been done in terms of making new investments needed to increase efficiency in water use and

to introduce new water supply. One of the highest priorities of the Government is developing irrigation dams."

4.5 Government Regulations: Licensing and Monitoring

Abstraction Licensing

The situation on water licensing is unclear from the reports and studies that have been reviewed. Environmental permits and licensing are the responsibility of the Afghan National Environmental Protection Agency (NEPA), but no specific reference exists for water licensing which may now be within the responsibilities of MoEW.

To avoid unplanned depletion of water resources and to manage competition for water resources the government should implement a regime of water licensing and abstraction monitoring for all public, industrial, commercial and irrigation supplies. This will require a licensing agency under the MoEW which should implement an agreed methodology for setting the available yields from water resources and sharing licensed quotas.

Charging for water

Tariffs for water and sewerage charges are in place through AUWSSC, however few customers actually pay the charges. (reference: meeting with Director General AUWSSC, Kabul, 08.04.12.) These will need to be applied within the framework of the current legislation with a clear methodology to account for income from these charges.

The greatest challenge will be the ability of water customers to pay charges. It may be expected that when the public water network is extended the use of private wells will continue in order to minimise any liability for charges. In setting the level of charges the government will need to take recognition of the difficult economic circumstances of the majority of the population. At a recent meeting with AUWSSC it was pointed out that tariffs charged by private companies were considerably in excess of those charged by AUWSSC by a factor of 10.

Pollution prevention and enforcement

Pollution of groundwater and the local rivers is a major concern for the Kabul City area. Simple steps are needed to control pollution from sewage and encourage protection of the groundwater, which provides the only means of water supply for up to 4 million people.

The sources of pollution are widely dispersed and will only be controlled with the support of the majority of the population.

A regime of regulation and enforcement will be needed within the new government regulations, but this will not be effective until practical measures have been taken to enable people to dispose of sewage from earth latrines and other waste in a safe manner.

Public Health Monitoring

From the information available within the various studies it appears that little or no monitoring is carried out for water quality, either for public supplies or to monitor for environmental risks. This is most likely caused by a lack of suitable laboratories, equipment and trained personnel to analyse samples.

The 2008 DACAAR analysis of water quality within aquifers beneath Kabul City indicates severe quality problems. In order to protect public health as far as practicable, public and private supplies must be analysed in a systematic way to determine levels of risks from contaminants.

5 KABUL RIVER BASIN: PROPOSED WATER RESOURCE STRATEGY

5.1 Objectives and Assumptions for the Strategy

The strategy for the development of the Kabul River Basin should be based around the following needs:

- Domestic water demand (urban and rural)
- Institutional and industrial demand;
- Irrigation;
- Hydro-power;
- Thermal or other power generation;
- Mining.

To simplify the strategy the following has been assumed:

- Rural demand will be initially be satisfied from springs or other suitable surface water sources and existing shallow or medium depth wells;
- Rural water demand will be extended under the World Bank program for rural water supply and sanitation;
- Irrigation will continue to be provided in the short term from existing sources generally along river valleys or from Karez;
- That no thermal power stations will be constructed in the short term within the basin, however they might be installed if fuel and water resources are available but only in the medium to long term;
- Planned large scale mining operations will proceed at Aynak and the iron ore mine at Hajigak; however only copper processing is expected to require significant water resources;
- Water demands from further exploitation of copper ore deposits within the overall Aynak area cannot be met from existing local water sources. Outline proposals are for mine investments to support the interbasin transfer of water from the Panjshir subbasin to supply either the mine or Kabul domestic supplies;
- Transfer from the Lower Kabul basin to supply either Kabul or mining operations are possible but will impose significant technical and financial restraints due to the length of transfer, difference in elevation and topography which will requiring tunnelling for a significant part of the route;
- Transfer from the Panjshir basin are practical but require significant investment

Existing summary situation on the Basin

- Water supplies for Kabul are from ground water aquifers in and around the city with recharge from the Logar-Upper Kabul sub basin. Water supplies for Jalalabad come from an impounding reservoir on the Kabul river;
- The main hydro-power stations are located on the Kabul river at Mahipar, Naghlu, Sarubi with smaller stations on the Salang and Logar rivers;
- No large scale mining currently in operation.

Any strategy should be acceptable to the local inhabitants and affordable. It should be noted that the existing water supply arrangement has worked relatively well in the past, being affordable to the majority. However the present arrangements have had a significant environmental impact within central Kabul where the aquifer has been depleted and the water quality within this aquifer has deteriorated through sewage contamination.

5.2 Review of Strategies Proposed by the KfW and JICA Studies

Existing strategies have been developed by the KfW and the JICA Studies to accommodate the following assumptions or objectives:

- Significant expansion of Kabul both in the number of inhabitants and per capita consumption;
- Increased demand for energy requiring a significant increase in hydro or other power generation capacity;
- Economic revival proposed to be jump-started by a number of large scale mineral or hydrocarbon extraction operations;
- Maintenance of irrigated land to ensure adequate supplies of food;
- Withstand the negative impact of adverse weather or climate change.

Strategies developed over the last 10 years by the KfW and JICA studies propose the following:

- Significant expansion of Kabul population from around 2.5 million in 2005 to around 6 million in 2015-2020;
- Significant increase in potable water per capita demand from around 20 to 30 LCD to an average of 60 LCD for the urban population;

- Piped water supply to be provided for the majority of the urban population;
- A new sewer network and treatment facilities to be installed for the majority of the urban area of Kabul;
- A storm water network for Kabul discharging to existing storm water channels;
- A new city to the North of Kabul to accommodate the proposed expansion;
- A large scale copper mine to commence operation as soon as possible near to Kabul and to utilise a significant part of the existing Logar river water resource;
- Industrial expansion within Kabul to ensure economic progress/survival;
- The increased need for potable water would come from a number of large impounding reservoirs on both the Logar-Upper Kabul and Panjshir sub basins;
- The transfer of water from the Panjshir sub basin by very large transfer pumping stations and trunk mains some 70km long with a hydraulic lift of around 400m;
- Some storage dams proposed for water supply would also provide hydro-power;
- Additional large hydro power units are proposed for the Panjshir River and rivers within the Lower Kabul sub basin.

An incremental strategy is therefore required which promotes the most plausible and highest priority solutions to meet the strategic water needs within the Kabul basin.

5.3 Summary of Options

The wider Kabul River Basin has adequate water resource for inhabitants, agriculture, mining and hydro-power to provide a part of the ever increasing energy needs of the country. However the resource is not available to meet the projected per capita demand for the city of Kabul without significant capital investment.

The JICA Study (Master Plan for Kabul) has estimated that per capita demand will rise from the current estimate of between 20-30 LCD to around 120 LCD for an urban population that is projected to expand from a current 2012 estimate of around 4 million to over 6 million within 20 years. Such a level of per capita consumption assumes that a piped water and sewerage network is available for at least 90% of the inhabitants.

Domestic water supplies for Kabul continue to be provided from the ground water aquifers within Kabul City and aquifers associated with rivers to the west and east of the city. With no sewer or storm water network, human and animal waste is having an

increasingly negative impact on the water quality of the central aquifer from which many of the inhabitants draw their water from shallow depth wells.

The conclusion from all reports is that the current water sources available for Kabul are inadequate, subject to increased levels of pollution from human and potentially mining activity and at significant risk under adverse weather conditions or the impact of long term climate change.

Options considered to meet growing demand include:

1. Increasing the current extraction rate from ground water in and around Kabul;
2. Extracting ground water from the Upper and Middle Logar river aquifers and transfer water to Kabul and Aynak mine;
3. Providing additional impounding reservoir storage near to Kabul at the proposed site at Shatoot;
4. Providing significant levels of storage and water transfer capability from the Panjshir valley to Kabul once funding secured to develop a piped water supply and sewerage system for the majority of Kabul inhabitants;
5. Providing additional storage on the upper reaches of the Logar river to maintain stream flow during adverse weather conditions.

Table 5.1 Summary of Options

Source	Current yield (m^3/d)	Total Potential yield[1] (m^3/d)	Potential Investment program[2]	Comment
Logar Upper Kabul Sub-basin				
Kabul GW Basin aquifer	Est. 99,000 (Table 2.4)	122,000	Short term	Potential to increase abstraction from Lower Logar aquifer
Middle Logar aquifer	Small & local	173,000	Short term	Currently partly used to supply irrigated agriculture and settlements. Abstraction likely to impact on Kabul GW basin aquifer yield. Currently allocated for Aynak mine but part of the yield could be available for Kabul. The statement on arsenic contamination[4] needs to be verified before progressing any investments.
Upper Logar aquifer	Small & local	173,000	Medium	Potential gravity supply, no feasibility study available combined with a claimed poor security situation. Currently partial used to supply agriculture and settlements
Deep aquifer				Reserve only as not significantly recharged
Shatoot Dam	0	266,000[3]	Medium	
Tariq Wardag and Kajab Dams			No study available	Upstream Logar, no feasibility study, agricultural areas. Potential storage for aquifer recharge and irrigation.
Sub-total		734,000		
Panjshir Sub-basin				
Panjshir Fan aquifer transfer	0	573,000	Medium /Long	Technically feasible with high annual operating costs. However no reliable data to support the anticipated yield
Salang and other dams	0	268,000	Long	Long term options to provide surface water for Kabul Metropolitan area (Salang yield from JICA Master Plan 2009 Exec Summary)

Note

(1) – JICA Study

(2) – Short term = 2 years, Medium Term = 10 years, Long Term = .>10 years.

(3) -Water resources Planning Report P00YAB Feb 2010

(4) JICA Master plan 2009 Sector report 3 water resources

5.4 Short Term Action Plan (2013-2014)

Set out below are short, medium and long term actions as part of the water strategy for the Kabul basin.

5.4.1 Logar-Upper Kabul Basin

a) Increase ground water extraction by installing more wells and transfer mains in the two main aquifers round Kabul. Carried out by AUWSSC under their Short Term Project (STP) to be completed by the end of 2013.

b) Drill and install at least two high yield production test wells (approx 175m^3/hr) in the Middle Logar aquifer at sites proposed in consultation with MCC and local Kabul agencies. The aim is to determine the impact of significant pumping from medium depth wells on the Logar river stream flow and the aquifer providing water for irrigation. Water abstracted from the wells could be used during the test period for irrigation. Additional test/ monitoring boring is required to determine the depth of the aquifer near to production wells and potential reliable yield.

c) Review available data on the interconnection of the Logar river middle and lower aquifers and the potential impact of significant extraction from the middle aquifer either for Aynak mine or a combination of supply for Aynak, irrigation and Kabul water supply;

d) Secure funding for Shatoot dam and commence tendering and contract award. Note this is a short term action prior to construction taking place.

e) Carry out a feasibility study for Kajab storage dam on the Logar river. Review the potential for Aynak mine (MCC) to fund construction as a part of their water supply requirement.

f) Commence studies on the Upper Logar aquifer as a potential source of water for Kabul/ Aynak mine.

g) Continue monitoring the status of the shallow aquifer under Kabul city to determine the negative impact of excessive extraction and pollution caused by human/animal waste.

h) Review rehabilitation requirements (if any) for the Chak Wardak diversion/hydro-power dam so that the dam remains in effective operation.

i) Secure funding for Kabul Municipality Medium Term Plans (MTP1-4: Extension of the Kabul Water supply system), currently proposed for completion by 2016.

j) Develop a specific master plan for sewerage collection and wastewater treatment and sludge disposal for Kabul. The master plan would be the first phase in developing a set

of feasibility studies which would be converted into specific investment programs for wastewater collection and treatment.

k) Finalise and agree water supply arrangement for Aynak mine and ensure that mine has security of supply.

l) Carry out a study on the use of irrigation within the Logar river and propose potential investments for the rehabilitation of existing irrigation channels, use of medium depth aquifers and assistance to farmers to change crop patterns.

m) Consider options for aquifer recharge, particularly in the middle Logar aquifer.

5.4.2 Panjshir Basin

a) Complete studies currently being undertaken by JICA on the likely yield and extent of the Panjshir fan aquifer.

b) Complete studies currently being undertaken by JICA for the transfer route from Panjshir fan aquifer to Kabul including locations of intermediate pumping stations, service reservoirs and future water treatment plants. Route review must also consider alternative sources from surface water of either Salang or Gulbahar dams.

c) Prepare studies on whether the Panjshir transfer scheme could be funded by proposed investment for Aynak North copper mine bid. Studies need to be finalised before bid documents are completed.

5.4.3 Lower Kabul Basin

There are realistically no short term options required, other than to progress development of hydro-power stations proposed for the basin.

5.4.4 Short Term Action Plan Budget Estimate

Summary budget estimates are provided in the following table for work identified above:

No	Description	Remarks	Budget estimate USD x 1,000	Duration
Logar-Upper Kabul Basin				
1	Increased ground water extraction and distribution	STP current, estimate not included in budget	(70,000)	Finalised 2013
2	Production test wells in the Middle Logar		250	Finalised end 2013
3	Data review interconnection middle and lower Logar aquifers (following review of WRPU Kabul Basin Investment Plan due for issue in July 2012)		100	Mid 2013
4	Secure funding Shatoot Dam	Budget estimate	200	End 2014
5	FS for Kajab dam	Includes surveys	2,500	End 2014
6	Studies Upper Logar Aquifer	Includes surveys	1,000	End 2014
7	Monitor Kabul Aquifer	Includes surveys	1,000	End 2014
8	Rehab of Chak Wardak Dam		500	End 2014
9	Secure funding for MTP 1-4		200	End 2013
10	Master plan Kabul Sewerage		1,500	End 2014
11	Water supply for Aynak	Funded by MCC		End 2013
12	Irrigation study Logar river		500	End 2014
	Total Logar-Upper Kabul Basin		**7,750**	
Panjshir Basin				
1	Studies likely yield of Panjshir fan aquifer (currently in had by JICA)	Includes surveys and test wells	Work underway	End 2014
2	Feasibility study transfer Panjshir to Kabul (currently in hand by JICA)	Includes surveys	Work underway	End 2014
3	Studies for Aynak North to provide investment for Panjshir transfer	Estimate	1,000	End 2014
	Total Panjshir Basin		**1,000**	
Lower Kabul Basin				
	No studies proposed			

5.4.5 Short Term Action Plan Program

The development of terms of reference for feasibility and other studies could be completed by the end of 2012.

Tendering, award and implementation of the proposed studies would be completed within the proposed 2 year short term program

Tendering, award and installation of production wells and additional bore holes would again be completed within 1 year commencing in 2013 allowing at least 1 year for analysis and implications of extraction from the middle Logar aquifer.

5.4.6 Risk

There is considerable risk associated with developing the terms of reference for the significant number of studies proposed within the short term program. The expectation is that roughly 50% of the required TOR's will not be developed until the middle of 2013 or year 1 of the program.

Provisional estimates for studies are realistic where they do not involve significant geological or other surveys. Where these are required then estimates should have significant contingency applied of up to 50%.

5.5 Medium Term (10 Year) Action Plan (2015-2025)

5.5.1 Logar Upper Kabul Basin

a) Commence construction of Shatoot dam, based on current feasibility study construction will take 5 years commencing, once funding secured, in 2014/2015.

b) Implement Kabul Medium Term Plan for water supply. Funding currently expected to be in place by 2014 with a 3-5 year investment program.

c) Construction of Aynak copper mine complex including water supply, tailings dam, processing unit and open pit extraction.

d) Consider the potential need for construction of Kajab dam as part of the water supply for Aynak mine. Dam construction estimated to take 2-3 years subject to relocation issues and costs of inhabitants within the proposed dam storage area. The understanding of the need for the construction of this dam will develop from the proposed investigations into the groundwater potential of the middles and upper Logar aquifer and the study into the potential for aquifer recharge.

e) Construction of phase 1 wastewater collection and treatment for Kabul. Phase 1 estimated to take at least 5 years at an expenditure rate of 50 MUSD per year. Construction would commence earliest in 2015 once feasibility studies approved and funding secured.

f) Construction of subsequent phases of wastewater collection and treatment for Kabul. Expenditure rate anticipated to remain at a maximum of 50 MUSD per year.

5.5.2 Panjshir Basin

a) Secure funding and commence construction for the transfer of ground water from the Panjshir fan aquifer to Kabul. Detail design, construction and commissioning of the large transfer scheme would take a minimum of 5 years commencing in 2016/17 dependent on the completion of feasibility studies and related EIA's and any other economic or social studies required before construction can commence.
b) Continue the development of feasibility studies for the Salang and Gulbahar dams and related water transfer routes to Kabul.

5.5.3 Lower Kabul Basin

Progress through feasibility study to actual construction any of the three main hydro-power units on the lower Kabul, Laghman and Konar rivers.

5.6 Long Term (30 Year) Action Plan (End 2045)

5.6.1 Logar Upper Kabul Basin

Other than continued investment in municipal water and wastewater infrastructure for Kabul, all major investment proposed for this basin should have been finalised or close to completion by the end of the medium term action plan in 2025.

Potential studies and associated investment would be carried out to secure additional storage on the Logar river and any of its tributaries to ensure water available for irrigation, rural supplies and adequate storage for aquifer recharge.

5.6.2 Panjshir Sub basin

Proceed from approved studies, secure funding and construction for any of the approved storage and transfer schemes for the Salang and or Panjshir rivers. The expectation is

that at least one of the proposed schemes will be implemented by the middle of the long term program.

5.6.3 Lower Kabul Sub basin

Continue with the installation of hydro-power units as and when funding is secured

6 INVESTMENT COSTING

6.1 Outline Capital Investment

The key variable in the analysis is the impact of growth and per capita demand for Kabul metropolitan area and the availability of funds to support the growth. Fresh water for Aynak mine has been assumed constant over the 30 year estimated life of the mine.

Three investment options have been considered and are described below:

Low: Extension of Kabul potable water network carried out in accordance with current investment plans covering MTP 1-3 as proposed by KFW and AUWSSC. No investment in sewerage or additional storage schemes.
Medium: Improved levels of water supply leading to further expansion of Kabul with funding made available for piped water supply and sewage collection and treatment for at least a part of the city.
High: Significant funding available for water and sewerage within Kabul combined with strategic investment in water resource.
Note: Water resource for Aynak copper mine is assumed to be minimised by high use of recycling within the processes and hence would require a maximum of 35,000 m^3/day.

6.2 Investment Scenarios: Assumptions

Low option

- Minimum investment in piped water supply for Kabul, no sewerage investment.
- Water supplies expanded by making full use of existing local aquifers.
- Significant risk of pollution of the central Kabul aquifer from human and animal waste; this can only be mitigated by investment in a centralised sewer network.
- Further expansion in both demand and population are constrained by a limited water resource.

Medium option

- Water supplies for Kabul can be provided from ground water with storage plus transfer from upper aquifers of the Logar river.
- Available water resources are improved as a direct result of increased levels of funding.

- Funding in municipal infrastructure is required to make use of the increased water resources.
- Local water sources including storage dams at Shatoot on the Maidan river will be just sufficient to meet increased demand.
- Significant investment required for wastewater collection and treatment facilities.

High option:

- Significant levels of funding are available water resource development including water transfers from the Panjshir sub basin
- Significant extensions to the potable water network and a sewer network with associated wastewater treatment facilities.
- Major transfer facilities required from the Panjshir sub basin including storage, transfer trunk mains and high lift pumping stations.

6.3 Overall Capital Cost Estimates

Capital investment for the low option could be completed within 5 years assuming funding available. The medium option could be completed between 8 and 12 years based on completion of the Shatoot dam within 7 years and the security situation making the transfer from the upper Logar aquifer a practical solution. The high option would realistically take around 15-20 years to implement as major infrastructure projects are required for the Panjshir transfer scheme.

Budget estimates of capital investment for proposals outlined in Section 5 are provided below in table 6.1

Table 6.1: Outline Capital investment

No	Investment component	description	Rate (USD)	Units	Quantity	Estimate (USD)	Estimated completion	Funding
1	**Extension of ground water Logar lower aquifer**							
		New wells	140000	No	10	1,400,000		
		Trunk main	400	$/m	10000	4,000,000		
		Interconnecting pipework	100	$/m	5000	500,000		
		Total				5,900,000	2013	Available
2	**Extension of ground water capacity Upper Kabul river**	New wells	140000	No	5	700,000		
		Trunk main	300	$/m	5000	1,500,000		
		Interconnecting pipework	100	$/m	3000	300,000		
		Total				2,500,000	2013	Available
3	**Storage Maidan river**	Shatoot dam	193.3	MUSD	1	193,300,000		
		Displacement costs	11.4	MUSD	1	11,400,000		
		Trunk main	14.79	MUSD	1	14,790,000		
		Treatment Plant	76.8	MUSD	1	76,800,000		
		Irrigation	16.4	MUSD	1	16,400,000		
		Total				312,690,000	2019/2020	None
4	**Extraction upper Logar aquifer**	New wells	140000	No	30	4,200,000		
		Trunk main	800	$/m	70,000	56,000,000		
		Interconnecting pipes	200	$/m	20,000	4,000,000		
		Total				64,200,000	2018	None
5	**Extraction middle Logar aquifer**	New wells	140000	No	30	4,200,000		
		Trunk main	800	$/m	40,000	32,000,000		
		Interconnecting pipes	200	$/m	20,000	4,000,000		
		Total				40,200,000	2016	None
6	**Panjshir Transfer**	River barrage	9.92	MUSD	1	9,920,000		
		Pumping station	2	MUSD	1	2,000,000		
		Trunk main	80	MUSD	1	80,000,000		
		Main pumping station	8	MUSD	1	8,000,000		
		Booster pumping station	8.5	MUSD	1	8,500,000		
		Trunk main	42	MUSD	1	42,000,000		
		Total				150,420,000	2020+	None

Table 6.2 Outline Municipal Investment Short & Medium Term Plans

No	Investment component	description	Rate	Units	Quantity	Estimate USD	Estimated completion	Funding
1	Short term plan, wells, reservoirs and network extensions	STP Not included in new investment				50,000,000	2013	Available
2	Estimate 800 km of new potable water network, total length 1,300 km	MTP1-3				186,000,000	2016/17	Scheduled but not available yet
3	Additional water related investment	MTP4				20,000,000	2020	Not available
4	Estimate of 1000km of sewer network	Sewerage network	250	$/m	1,000,000	250,000,000	2018	None
5	Associated WWTP	WWTP	100	$/PE	1,000,000	100,000,000	2018	None
		Total				556,000,000		

Table 6.3 Summary Investments

Funding Option	Description	Estimate $US Million
Low	Completion of STP	Available
	Completion of MTP 1-3	186.0
	Total	**186.0**
Medium	Completion of STP	Available
	Completion of MTP 1-3	186.0
	Extraction and transfer Middle Logar river aquifer	40.2
	Storage Maidan river Shatoot dam	312.7
	Extraction upper Logar aquifer	64.2
	Sewerage network	250.0
	WWTP	100.0
	Total	**953.1**
High	Completion of STP	Available
	Completion of MTP 1-3	186.0
	Extraction and transfer Middle Logar river aquifer	40.2
	Storage Maidan river Shatoot dam	312.7
	Extraction upper Logar aquifer	64.2
	Panjshir transfer	186.5
	Additional potable water network for Kabul	200.0
	Sewerage network phase 1	250.0
	WWTP phase 1	100.0
	Additional sewerage Phase 2	250.0
	Additional treatment Phase 2	100.0
	Total	**1,689.6**

Regarding extraction from the middle Logar aquifer for both Kabul water supply and Aynak. In the short term this is a realistic proposal as capital investment in wells and transfer mains could be completed before the mine and its processing plant commence operation. The allocation of the middle aquifer only for Aynak seems to be unjustified especially when fresh water make-up can be reduced if the latest technology is used for ore concentration. However analysis of middle Logar aquifer ground water is urgently required to review the statement that water may contain arsenic and be unsuitable for domestic use.

Operating and Maintenance costs

O&M costs have not been developed in detail for any option at this stage. However annual operating costs for the first two options are reasonable as infrastructure proposed is in current use and transfer schemes rely on gravity flow rather than high lift pumping stations and long large trunk mains. There will be a considerable increase in annual costs for the high option due to the need to maintain both water and wastewater treatment facilities. Whether these costs are affordable to the general population has not been reviewed.

7 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

7.1 Kabul River Basin

Options for the Kabul river basin are very strongly influenced by the demand projections for Kabul and any additional water resource required for proposed mining operations at Aynak.

Options considered necessary to meet growing demand include:

1. Increasing the current extraction rate from ground water in and around Kabul;
2. Extracting ground water from the Upper and Middle Logar river aquifers and transfer water to Kabul;
3. Providing additional impounding reservoir storage near to Kabul at the proposed site at Shatoot;
4. Providing significant levels of storage and water transfer capability from the Panjshir valley to Kabul once funding secured to develop a piped water supply and sewerage system for the majority of Kabul inhabitants;
5. Providing additional storage on the upper reaches of the Logar river to maintain stream flow during adverse weather conditions.

The key to securing increased levels of extraction from ground water sources is improved levels of monitoring of all aquifers currently and proposed to supply Kabul. Without monitoring of the existing situation decisions cannot be made on whether outline proposals to make full use of this resource are workable. In addition without significant investment in the potable water network and more importantly wastewater collection and treatment much of the proposed investment in storage or other facilities will be compromised.

7.2 Planning and Legislation

We recommend that consideration should be given to the following actions for implementation over next 2 years in order to improve the potential of the Kabul River Basin water supplies:

- Implement regulation and licensing (reforms in legislation and/or practice) as summarised in Section 4.5
- Agree/ confirm planning and approval processes for water resources projects

- Determine mechanisms for funding investment in Capital projects

7.3 Aynak Water Supply

Ground water from the Middle Logar aquifer is the only water source available in the short term for the mine. Its extraction should be designed, monitored and controlled to cause the minimum disruption to other water users. This will require close monitoring and, in the event of deterioration, pre-agreed preventative measures must be taken at established trigger points.

The ore processing plant should be designed on the basis of maximising the reuse of water.

Advantage should be taken from investments at the mine to consider funding additional storage on the Logar river potentially at the proposed Kajab site on the upper reaches of the Logar river. Such a dam could provide the necessary storage for recharge of the Logar river, additional water for irrigation and require no additional funding.

7.4 Short Term Actions

In terms of immediate actions we recommend that the following key tasks are set underway:

1. Establish consultation with MCC to fully understand their water supply plans in terms of source, demand and programme. The outcome of this consultation should be shared with interested parties.
2. Seek for the formal issue of the ESIA prepared for the Aynak mine as soon as possible.
3. Prepare a comprehensive brief for test wells to be located in the middle Logar aquifer. The brief should include a programme of test pumping, monitoring and analysis to establish the safe yield of the aquifer and individual production wells, the optimum production well layout, the water quality and the impact of abstraction on current users, including consideration of the impact of abstraction on the flow interconnection between the middle and lower Logar aquifers.

4. Commence consultation with current users of the water resources within the aquifer once the water demand of the Aynak mine and associated environmental issues are understood.
5. Work with AUWSSC to secure funding for MTP 1-4 Kabul water supply extension.
6. Commence with the development of a brief for consultancy services to consolidate a wastewater master plan for Kabul.
7. Develop a brief for immediate action to implement water quality monitoring (for standard suite of WHO parameters) across the Kabul urban area, to include all AUWSSC and Microroyan public sources (unless this has recently been introduced) plus a statistically significant number of private wells.

APPENDIX 1:

List of Reports Reviewed to Compile the Kabul River Basin Report

1(a) SOFRECO Interim MHS SESIA

1(b) SOFRECO Baseline MHS SESIA

1) Scoping Strategic Options for development of Kabul River Basin
2) Screening Report of Aynak ESIA
3) USGS Geohydrological Report – Aynak Minerals Area
4) Pell Frischmann Aynak Formal Report (Final)
5) SR29 Water Consumption Copper Mines – Arizona
6) USGS Availability of water in Kabul Basin
7) USGS Groundwater levels Kabul Basin
8) JICA Master Plan for the Kabul Metropolitan Area 2009:
    i) JICA: EIDJR09107 Executive Summary
    ii) JICA: EIDJR09108 Main Report parts 1&2
    iii) JICA: EIDJR09108 Sector 03 Water Resources parts 1,2 &3
    iv) JICA: EIDJR09108 Sector 04 Ground Water parts 1,2 & 4
    v) JICA: Groundwater Resources Potential in Kabul Basin - Executive Summary
9) KfW Study 2004
10) DACAAR Groundwater Natural storage and Water Quality Concerns in the Kabul Basin 2010 (slide presentation)
11) Afghanistan Statistical Yearbook 2010-11

APPENDIX 2:

List of Abbreviations

LCD	Litres/capita/day (per capita water supply or demand)
m^3/d	Cubic metres per day (flow or usage)
JICA Study	Japanese International Cooperation Agency: "The Study for the Development of the Master Plan for the Kabul Metropolitan Area in the Islamic Republic of Afghanistan 2009" plus supplementary reports
KfW Study	Kabul for Water group: "Feasibility Study for the Extension of the Kabul water Supply System - January 2004"
DACAAR	Danish Committee for Aid to Afghan Refugees
MoM	Ministry of Mines
MoEW	Ministry of Energy and Water
CAWSS	Afghan Central Authority for Water Supply and Sewerage
AUWSSC	Afghan Urban Water Supply and Sewerage Corporation
MCC	Mining Company of China
NEPA	National Environmental Protection Agency

APPENDIX 3: ENHANCED AQUIFER RECHARGE

See separate attachment.

Chapter 13
Enhanced Aquifer Recharge

Krishna R. Reddy*

Abstract Enhanced recharge is defined as any engineered system designed to introduce and store water in aquifer. This chapter presents the benefits of enhanced aquifer recharge and describes the different methods to recharge aquifers. The applicability, advantages and limitations of each method are identified. Clogging of the recharge systems is a major concern and must be addressed during operation and maintenance of the systems. In addition to technical aspects, one must consider institutional and legal issues in selecting and developing recharge methods. A rational approach must be followed in the design, construction and operation of any recharge method. Numerous aquifer recharge projects have been successfully developed and implemented worldwide.

Keywords Aquifer, groundwater, depletion, recharge

13.1 Introduction

The basic concepts of groundwater hydraulics include vadose zone, unconfined aquifer and associated water table, confining units, and confined aquifer and associated potentiometric levels (e.g., Freeze and Cherry, 1979; Sharma and Reddy, 2004). If the discharge from any aquifer is less than or equal to the natural recharge, there is no concern with the depletion of groundwater in that aquifer. However, if the discharge from the aquifer exceeds the recharge, groundwater depletion occurs. The depletion of groundwater is also known as groundwater overexploitation and is mainly indicated by the decrease in water levels/potentiometric surface levels. The groundwater depletion can lead to short supply of water as well as environmental degradation.

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C.J.G. Darnault (ed.), *Overexploitation and Contamination of Shared Groundwater Resources.*

Enhanced recharge is defined as any engineered system designed to introduce and store water in aquifer. Enhanced recharge is also commonly known as artificial recharge or managed recharge. Enhanced recharge must be distinguished from incidental recharge. Incidental recharge is defined as recharge that reaches an aquifer from human activities not designed specifically for recharge. Some examples of incidental recharge sources include septic tank, leach fields, stormwater retention ponds, percolation from irrigation, and leaking water or wastewater pipes and tunnels. Incidental recharge may be source of groundwater contamination; therefore, it must be assessed carefully.

There are several benefits of enhanced recharge. The enhanced recharge can stabilize or raise groundwater levels, smooth out supply/demand fluctuation, reduce loss through evaporation and runoff, store water in aquifers for future use, and impede storm runoff and soil erosion. In addition, enhanced recharge should be an integral part of any water management strategy to improve water quality and smooth fluctuations, maintain environmental flows in streams/rivers, manage saline intrusion or land subsidence, and dispose/reuse of waste/stormwater.

Different sources may be available for the recharge water. These sources include excess surface water from streams, canals, lakes, reservoirs, stormwater runoff, treated effluents, reclaimed wastewater, imported water from other areas, groundwater from other aquifers, and potable water (often for storage and recovery). In the United States, monitoring data shows that the flow in many rivers and lakes exceeds the median flow; therefore, this overflow could be used as an excellent source of recharge water. Stormwater runoff water if properly collected could be another valuable source of recharge water. Treated effluents and reclaimed wastewater should be evaluated for their quality prior to deciding on their suitability as recharge water.

This chapter presents different enhanced recharge methods, various design and operation considerations, and institutional and regulatory issues. Next the chapter presents a rational methodology to design recharge systems. Finally, the chapter presents a few case studies demonstrating the successful completion of enhanced recharge of groundwater.

13.2 Enhanced Recharge Methods

The most common methods to enhance recharge groundwater can be grouped under (i) surface infiltration methods which involve percolation of recharge from or near the ground surface, (ii) vadose zone infiltration methods which involve percolation of recharge water at some depth below the ground surface, but within the vadose zone, and (iii) direct injection methods which involve direct injection of recharge water into the aquifer (ASCE, 2001; Bouwer, 2002; Topper et al., 2004; WDNR, 2006). In addition to these common methods, few other methods are also used. For example, artificial storage and recovery (ASR) method involves

injection of recharge water directly into the aquifer using wells, but the recharge water is later recovered from the same wells. Riverbank filtration method is another method that gained much attention recently which uses well fields placed near surface water bodies with the intention of inducing surface water into the aquifer to provide some or all of the water produced by the well field. In developing countries, rainwater harvesting method, which involves connecting the outlet pipe from a guttered roof-top to divert rainwater to either existing wells or other recharge structures, is being used. More details on the common aquifer recharge methods are provided in this section.

13.2.1 Surface Infiltration Methods

In surface infiltration methods, recharge water is applied at the surface above an unconfined aquifer in man-made or natural depressions to infiltrate down to the underlying water table, ultimately causing the water table to rise. These methods are often preferred due to lower cost, greater simplicity, and lower operation and maintenance costs. However, these methods require that the soils from the infiltration location to the top of the aquifer possess high vertical permeability. The different surface infiltration methods, as depicted in Figure 13.1, include infiltration ponds or basins, infiltration ditches, stream channels, land applications, and in-channel systems (e.g., percolation ponds, leaky dams and recharge releases, sand storage dams, and subsurface dams).

Infiltration ponds or basins are essentially artificial depressions that receive water and allow the water to recharge an aquifer through the bottom of the structure. Existing excavations, such as gravel pits or leaky reservoirs, are often used for recharge basins. A series of recharge basins may be used to increase the recharge from a larger area.

Infiltration ditches are linear structures, such as canals and ditches, which are designed to leak water through their bottoms to recharge an aquifer. These can sometimes be built in areas where the topography or limits of available land preclude the use of infiltration ponds. Infiltration systems can be designed as lateral systems, dendritic systems, or contour systems. Lateral systems consist of small ditches which protrude at right angles from canals, flow control gates at head of the systems, furrow depths related to topography to maintain uniform velocity, and collection of runoff in a canal further down slope to routes water back in source stream. The dendritic systems divert flow from the main canal to a series of successive and smaller ditches, gates control flow to each ditch series, and bifurcation of ditches continues until all water has infiltrated. The contour systems consist of spreading water through ditches that follow land contours and return water through ditches to source stream at the end of the spreading area and at the lowest point.

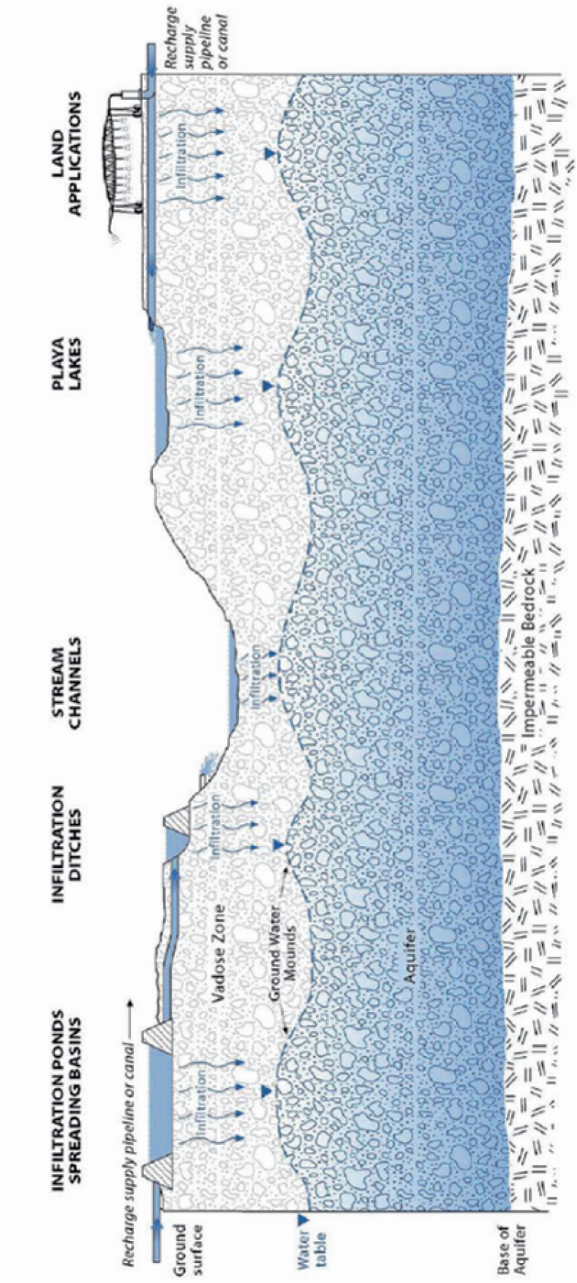

Fig. 13.1 Surface infiltration methods (Topper et al., 2004)

Stream channels can be used as infiltration ditches providing that the configuration of the water table allows the stream to infiltrate water into the ground. The stream channels may be modified with diversions, ditches, and check dams todecrease flow velocities and allow longer storage within the channel so that greater percolation can occur.

Land application includes a variety of methods where water is applied to the land surface. Recharge can occur if the application rate exceeds the evapotranspiration rate of the area. Common land application methods include: flooding, over irrigation, and some wastewater disposal systems that use irrigation methods. Flooding can essentially include diverting a stream and introducing recharge water into an impoundment area created by temporary dikes or embankments and allowing excess water to reenter into the source stream. Various irrigation techniques have been developed, such as overland flow, ditches and furrow, sub-irrigation, flooding or spray, which can readily be used to recharge the aquifers.

Various in-channel modifications can be made to enhance storage and increase infiltration of recharge water. As shown in Figure 13.2, these modifications include percolation ponds, leaky dams and recharge releases, sand storage dams, and subsurface dams.

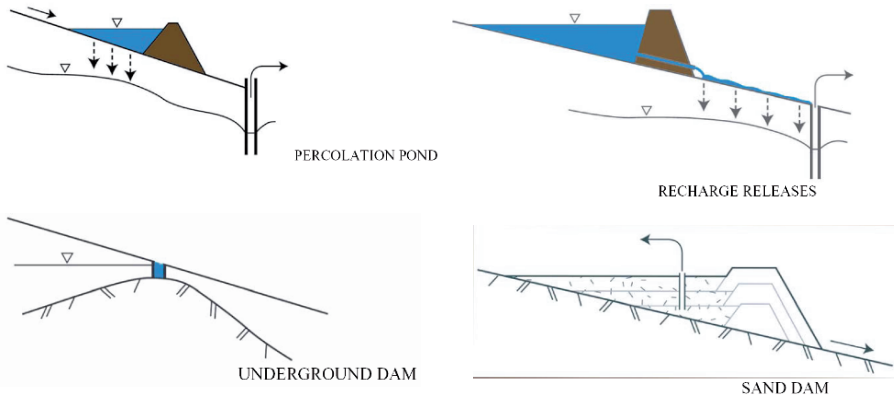

Fig. 13.2 In-channel modifications to enhance recharge (Gale, 2005)

Surface infiltration methods are applicable to unconfined aquifers with surface exposure and the aquifer materials may be alluvium, semi-consolidated, sediments at outcrop, and highly fractured bedrock. The advantages of these systems include initial low capital cost, simple maintenance, low operation and maintenance costs. Surface infiltration methods can use untreated surface water, and can co-exist with recreation use or wildlife habitat. Some disadvantages of these methods are that they require a near surface aquifer, and a permeable soil profile with high vertical permeability. High evaporation losses and groundwater vulnerability to surface contamination are disadvantages that make these method potentially incompatible with nearby land uses. Surface infiltration methods also require frequent maintenance to prevent clogging.

13.2.2 Vadose Zone Infiltration Methods

Vadose zone infiltration methods are used when near surface soils have low permeability or other land uses are not compatible with surface infiltration facilities. In these methods, recharge water is introduced at some deeper depth beneath the land surface (within the vadose zone) and then allowed to infiltrate into the unconfined aquifer. The most common methods are depicted in Figure 13.3 and include trenches and galleries, dry wells, infiltration shafts, and infiltration pits.

Infiltration trenches are excavated through shallow impermeable soils to facilitate recharge, use perforated pipes or permeable fill to infiltrate water. Infiltration galleries consist of multiple trenches. Trench systems can also be covered and used for other purposes such as parking lots, sports fields.

Dry wells are completed above the water table in the unsaturated zone. The wells can be completed with screens or slotted casing and are usually used to move water past a perching zone that is too deep for a trench system.

Infiltration shafts are large-diameter excavations drilled through a perching layer, but completed above the water table. The shafts can be completed with slotted casing or screens, or filled with permeable fill such as gravel and completed as an open hole. Infiltration pits are similar to infiltration shafts but are larger in diameter and may not be circular in shape.

Vadose zone infiltration methods are applicable to unconfined aquifers containing alluvium, semi-consolidated sediments at outcrop, or highly fractured bedrock. These methods are advantageous in that they can be used where surface layers of low permeability preclude surface infiltration, can co-exist with other surface urban uses such as parking lots and recreation facilities, and minimize evaporation losses. The disadvantages of these methods are higher initial capital costs, limited aerial extent, difficult to clean/maintain, and dependent upon near-surface geology.

13.2.3 Direct Injection Methods

Direct injection methods, as shown in Figure 13.4, involve injecting water directly into an aquifer using vertical wells. These wells are screened within the saturated portion of the aquifer and allow direct injection of recharge water. These wells may also be used for recovery purposes, if desired.

Vertical injection wells can be completed with slotted casing, well screens, or as open holes in competent formations. Injection wells minimize the vertical transit time of the water to the aquifer and can avoid unfavorable reactions between the water and soils or minerals in the unsaturated zone.

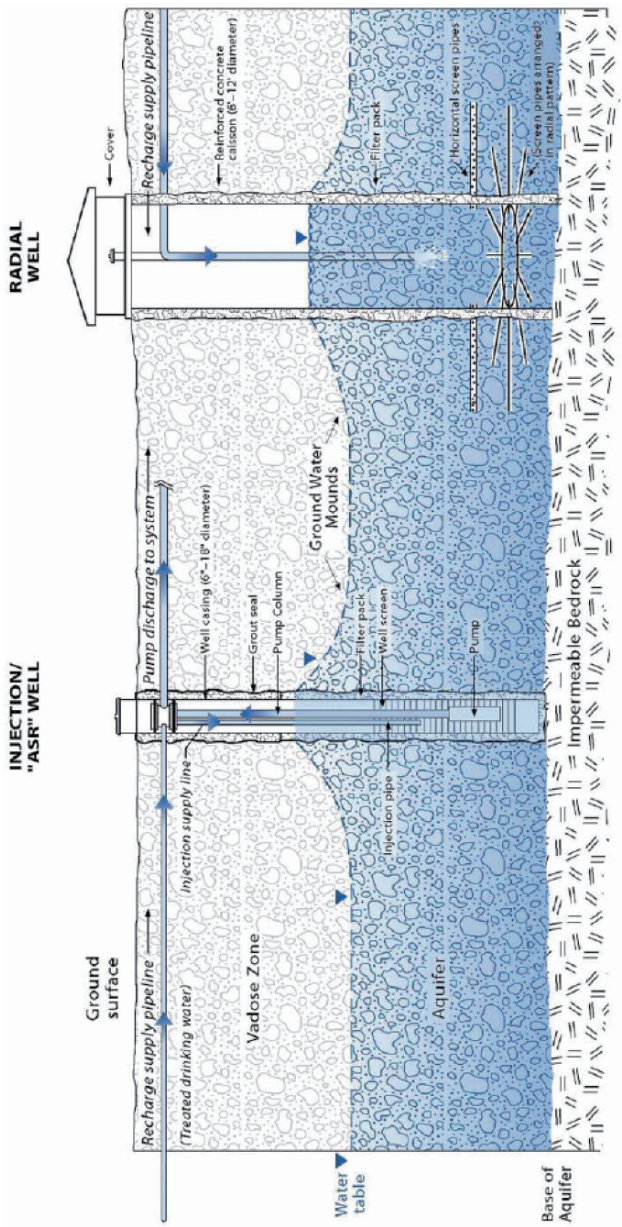

Fig. 13.3 Vadose zone infiltration methods (Topper et al., 2004)

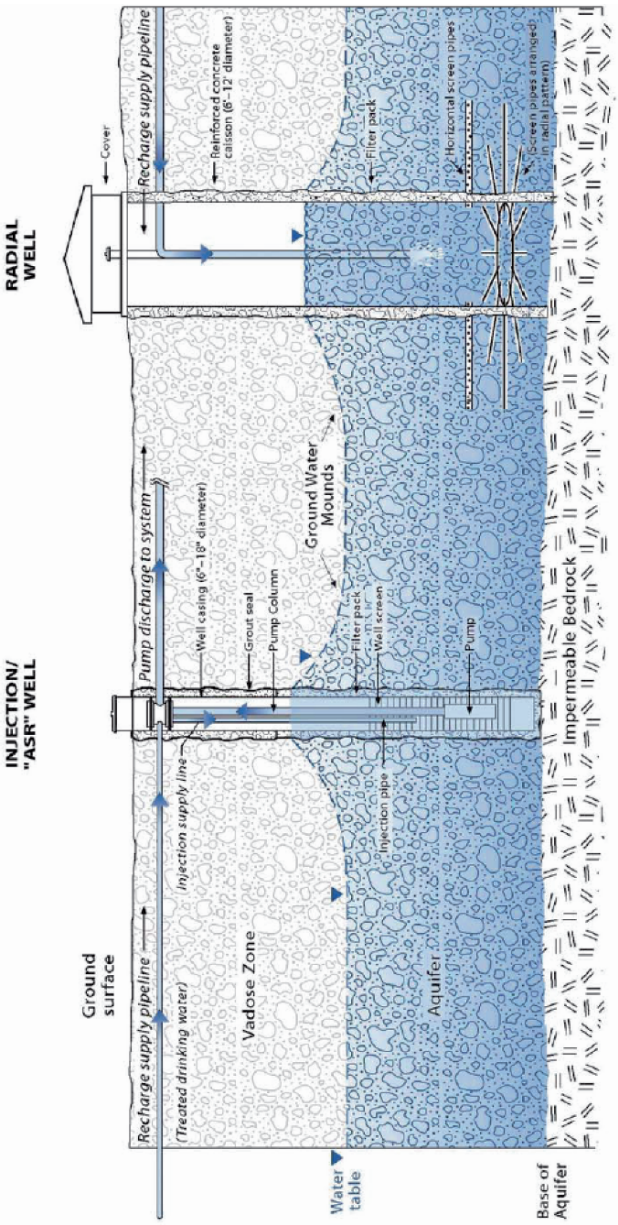

Fig. 13.4 Direct injection methods (Topper et al., 2004)

The direct methods are applicable to unconfined aquifers with limited surface exposure and confined aquifers consisting of deep alluvium and sedimentary bedrock aquifers. The advantages of these methods are that they can be used

where vertical permeability is limited, occupy small surface areas, can fit in with most land use patterns, and can utilize existing water supply infrastructure. The disadvantages of these methods are high capital costs when existing infrastructure is not available, high energy requirements, high operation and maintenance costs. It also requires frequent pumping to remove clogging, pretreatment to drinking water standards, and tight control over source water quality. Additionally, contamination from recharge would be difficult to remediate.

13.3 Design, Operation, and Other Considerations

In planning and designing any recharge systems, one must consider the following: (1) hydrogeological considerations, (2) source water considerations, (3) operation/maintenance considerations, particularly clogging of recharge systems, (4) institutional and management issues, and (5) legal and regulatory issues.

13.3.1 Hydrogeological Considerations

As depicted in Figures 13.5 and 13.6, the effectiveness of recharge systems is extremely dependent on the site's hydrogeology. Recharge system must be located with in or up-gradient of the aquifer. The type of recharge systems depends on the type of the aquifer, confined or unconfined. The depth to the top of the aquifer, the permeability of geologic formations overlying the aquifer, and the heterogeneous geologic conditions control the distribution of recharge water and the amount of infiltration into the aquifer. It must be recognized that raising the water level in an aquifer can have undesired negative impacts on surrounding structures and land, and these negative impacts must be properly evaluated.

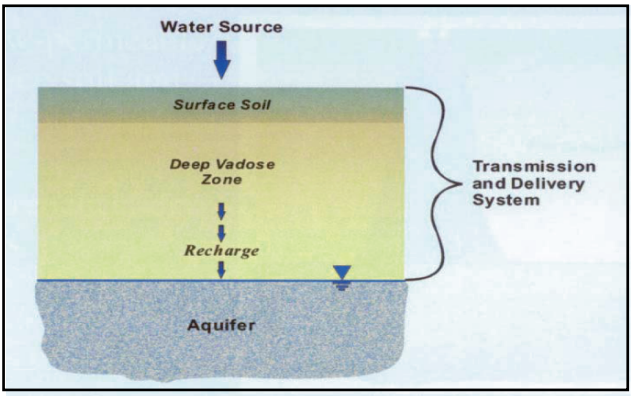

Fig. 13.5 Hydrogeologic considerations (Stevens, 2003)

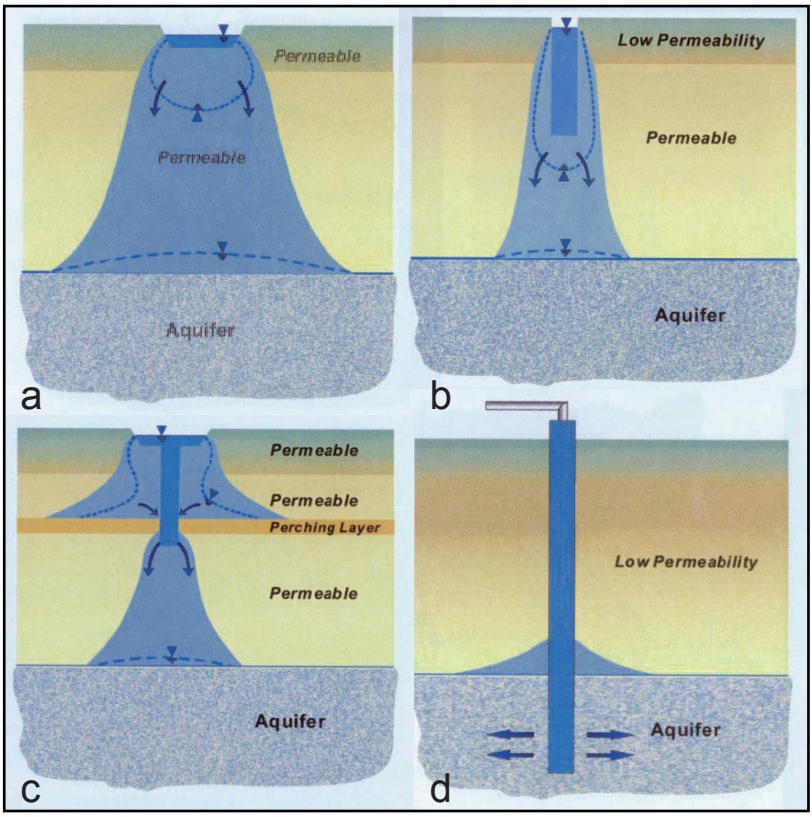

Fig. 13.6 Impacts of hydrogeologic conditions on recharge distribution (Stevens, 2003). **a** Permeable surface soil and vadose zone; **b** Low permeable surface soil and permeable vadose zone; **c** Perched low permeable layer in vadose zone; **d** Low permeable surface layer and vadose zone.

13.3.2 Source Water Considerations

Both availability (quantity) and quality of source water are important considerations. The sources of recharge water include surface water from streams, canals, lakes, reservoirs, reclaimed wastewater, storm runoff, imported water from other areas, groundwater from other aquifers, and treated drinking water. The quality of source water depends on the source. Generally, when the water is most abundant, the source is of poor quality (e.g., rivers with high turbidity). It then requires some form of treatment prior to recharge (e.g., simple sedimentation for river water). Wastewaters source requires a high cost treatment. Contamination of high quality groundwater, increase in solutes through mixing and dissolution, and adverse geochemical reactions due to source water characteristics are also possible.

13.3.3 Operation and Maintenance Considerations

Clogging of recharge systems is a critical issue. Silt or fine particles collected at the bottom of the recharge basin may cause clogging. Biological growth including bacteria and algae may also induce biological clogging. Other processes that may be responsible of clogging include air entrainment, swelling clay, and chemical precipitation (Figure 13.7).

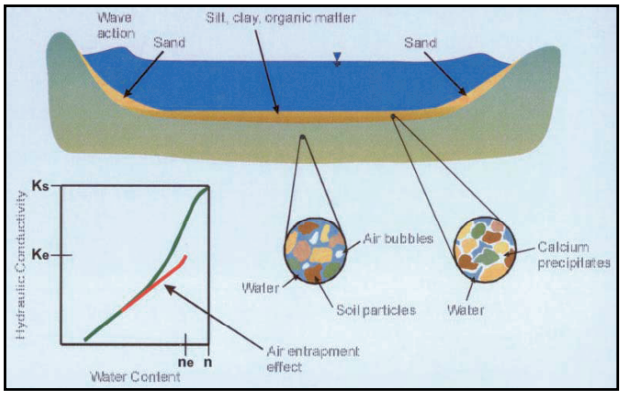

Fig. 13.7 Clogging of recharge systems (Stevens, 2003)

The extent of clogging depends on recharge water, soil, native groundwater, and design of recharge system. Cleaning varies from daily to periods of several years. Clogging layer must be removed by scraping off the material or raking or tilling the layer to enhance the permeability. The wave action to wash the side walls of the basin as well as dryout and cleaning are also used to remove clogging.

13.3.4 Institutional and Management Issues

Many institutional and management issues arise when dealing with recharge systems. These include water rights, land ownership, who pays and who benefits, who manages, private vs. public, etc.

13.3.5 Legal and Regulatory Issues

Legal and regulatory issues depend on the state and the country in which the recharge system is to be implemented. Many countries through their environmental

agencies regulate stormwater infiltration systems, wastewater infiltration systems, and injection systems.

13.4 Recharge System Design Methodology

A phased, systematic approach is needed for the design of recharge systems. Typical phases include:

- Phase I—Preliminary Activities;

  Data collection

  Develop a hydrogeological conceptual model

  Understand the hydrology (including meteorology)

  Quantify the components of the water balance

  Estimate aquifer storage capacity

  Assess the quality of groundwater and source water

  Environmental assessment

  Public involvement
- Phase II—Field Investigation and Test Program;

  Infiltration tests

  Subsurface investigations

  Water quality testing

  Environmental assessment
- Phase III—Design;

  Preliminary and final recharge system designs

  Hydraulic analysis/Groundwater modeling

  Pilot tests

  Economic analysis

  Environmental assessments

  Public involvement

  Engineering reports
- Phase IV—Construction and start-up;
- Phase V—Operation, maintenance, project review, and project modifications;
- Phase VI—Closure.

  Sampling for residual contamination and eliminating pathways for groundwater contamination

13.4.1 Selected Case Studies

13.4.1.1 Case Study #1

The Dorz-Sayban plain is located 115 km to the southeast of Larestan, Iran. The overexploitation of groundwater caused significant drawdown of water table (1.5 m/year) and deterioration of groundwater quality. 3,500 hectares of land are irrigated using groundwater in this plain. To decrease the rate of drawdown of the water table, five floodwater-spreading systems for recharge of groundwater were designed and constructed in the region (Figure 13.8). Inflow and outflow from the recharge system were measured for nine flood events. 83.5% of total inflow of 886,000 m^3 recharged the aquifer, and 70% of suspended load has settled in the system.

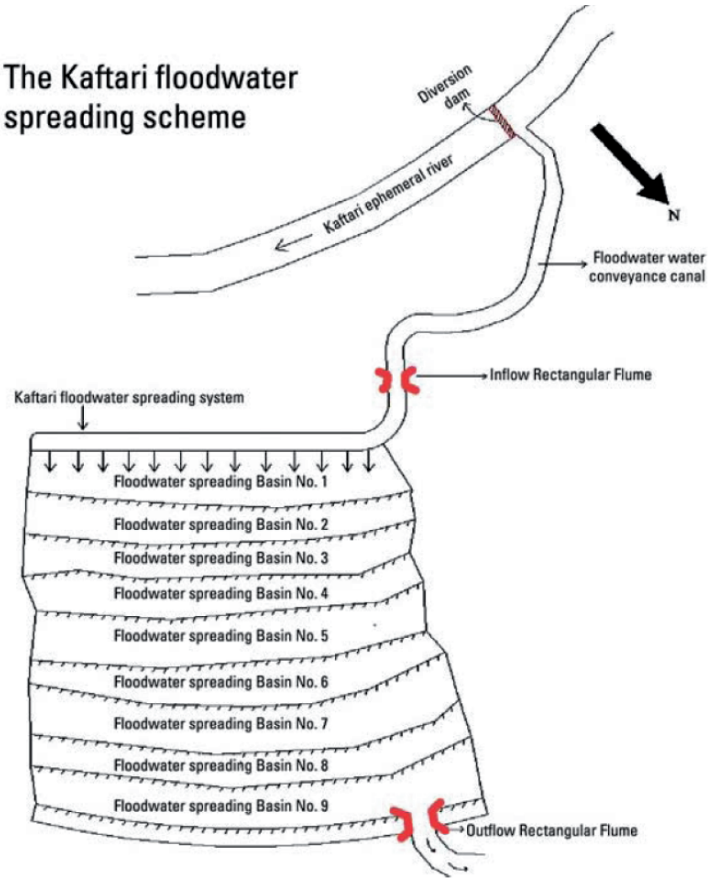

Fig. 13.8 Aquifer recharge water system used in Iran (Gale, 2005)

13.4.1.2 Case Study #2

Leaky Acres is a groundwater recharge facility operated near the City of Frenso, California. The groundwater recharge system was built in 1970 and consists of 26 ponds covering 200 acres. The surface soils are sandy, but two low-permeability aquitards are present at depth of 30–60 ft that are the limiting factor controlling the recharge rate. The water table is normally about 105 ft below ground surface. An average of 18 mgd of surface water from the local river is recharged to the groundwater at the site. The recharge system is taken out of service for 45 days each year to remove sediment and plugged materials from the beds.

13.5 Conclusion

Enhanced aquifer recharge should be an integral part of water management strategy. Surface and vadose zone infiltration methods are preferred for recharging shallow aquifers because of ease of operation and maintenance, and low cost. Direct injection methods are used to recharge deep confined aquifers, and recharge water in such case should meet drinking water standards. A systematic approach is recommended for the design of recharge systems. Clogging of recharge systems should be addressed through maintenance programs. Legal and regulatory issues should be properly addressed. Numerous successful enhanced aquifer recharge projects are reported worldwide.

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